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STUDIES ON THE EFFECT OF ROENTGEN RAYS UPON THE INTESTINAL EPITHELIUM AND UPON THE RETICULO-ENDOTHELIAL CELLS OF THE LIVER AND SPLEEN[1]

by

Sv. A. Chrom

In some experimental studies on the course of Breslau infection in universally irradiated mice, the bacteriological autopsy [after the method given by J. Örskov (13)] revealed the fact that the organs and blood of these mice were infected with bacteria belonging to the intestinal flora normally present in mouse, predominatingly colon bacilli. Among 52 mice which had been given universal irradiation with doses from 250 r to 450 r, 23 gave growth of colon bacilli and cultures from organs and of blood, whereas such growth could be demonstrated only in 1 out of 35 control mice. As the striking difference between the two groups of mice with regard to the frequency of demonstrable infection with Bac. coli cannot be merely accidental, it is made the subject of further investigation as presented in the present paper.

Technique and Material

The radiation was given with a »stabilivolt» apparatus from Siemens-Schuckert, 160 kilovolts, 4 milliampères.

Here the dose of Roentgen-rays is expressed by *r*, measured in air. Control measuring of the amounts of radiation employed in these experiments is made every week with Küstner's dosimeter. These control measurings have shown that the apparatus has worked very constantly throughout the experimental period.

The radiation distance is recorded in every experiment, and in most instances it has been 42 cm., making the radiation intensity 12.4 r/min.

[1] Submitted for publication. May 20th, 1935.

From the state serum institute, Copenhagen (chief: Th. Madsen. m. d.). The radium station (physician in chief: J. Juul. m. d.). The institute of pathology, Bispebjærg hospital (chief: Bj. Vimtrup. m. d.).

All the radiations, universal as well as local, are given through a filter of 0.5 mm. copper + 3 mm. aluminum. Under the given conditions this means a radiation with dimidiation by 0.9 mm. copper. As the same filter is employed throughout, its thickness and composition will not be recorded anew in the various experiments.

In experiments with universal radiation, the field has been 20 × 24 cm.; in experiments with local radiation, the size of the field is recorded in each instance.

The animal material consists in white mice, weighing each about 20 gm. As far as practicable the experimental animals have been kept isolated individually, each in its own cage, for at least 8 days prior to the experiment. Whenever such a mouse has shown any sign of illness, especially symptoms of intestinal disorder, it has been removed from the stable at once. By insisting upon this preliminary quarantine it has been possible to cut down the incidence of spontaneous infection in the experimental animals to a minimal number.

The mice are kept on a diet of crushed oats (with the bran included) and dry wheat bread (soaked in water). The temperature in the stable is kept constantly at 18—20°C.

The bacteriological technique is described in detail in previous works by J. Örskov (14) and H. C. A. Lassen (6). The autopsy technique follows closely the method given by Örskov, Jensen & Kobayashi (13).

Universal Irradiation of Normal Mice

A group of normal mice were given universal radiation amounting to 550 r. Bacteriological autopsy was performed in from 3 to 10 days after the radiation. The cultural results are given in Table I.

In Table I and following tables the outcome of the cultures made from the various organs and blood is presented schematically as follows:

0	means	no bacterial growth whatever;
((+))	»	growth of 1 colony;
(+)	»	» » up to 10 colonies;
+	»	» » » » 50 »
++	»	» » » » 200 »
+++	»	a dense crowd of colonies or confluent growth.

The individual bacterial colonies are identified by means of Gram's method of staining and by the biochemical properties of the respective bacteria.

As seen in Table I, when normal mice are exposed to universal radiation with 550 r, and bacteriological autopsy is performed on such mice in 3—10 days after the radiation, it is practicable in most of these mice to de-

Table I

Cultures from Animals after Universal Radiation with 550 r (= 1 HED). Radiation time 44½ min. Skin target distance: 42 cm.

Mouse No.	Days after radiation	Cervical lymph gls.	Mesenteric lymph gl.	Spleen	Liver	Heart's blood
1	3	0	+	+	(+)	0
2	3	0	+++	0	0	0
3	3	0	+	0	0	0
4	3	0	+	+	0	0
5	4	0	0	0	0	0
6	4	0	+	0	0	0
7	4	0	0	0	0	0
8	6	0	0	0	0	0
9	6	0	++	0	0	0
10	6	0	0	0	0	0
11	7	+++	+++	+++	+++	+++
12	8	+++	+++	++	++	0
13	8	0	0	0	0	0
14	9	+++	++	+++	+++	+++
15	9	0	+++	+	+	0
16	9	+++	++	+++	+++	+
17	10	+++	+++	+++	+++	+++

monstrate the presence of an infection, and the bacteria isolated from these animals may all be classified as bacterial species that may be said normally to inhabit the intestinal canal in mice. During the first days after the radiation, this systemic infection is largely localized to the lymphatic apparatus of the gut; on the 7th day, however, there appears a marked change in the character of the infection, in the form of a very violent progression, going on to generalization.

It is only natural to think of the intestinal canal as a source of origin for the infection brought about by exposure to the Roentgen-rays, as the character of the isolated bacteria and the mechanism of the demonstrated infection are uniformly suggestive of this source of origin. *A priori*, however, the possibility cannot be excluded that the focal infectious process in the mesenteric lymph gland, spleen or liver may turn into a progressive infection when the animal is exposed to radiation. But, in a total of 207 normal mice, I (1) obtained growth of intestinal bacteria from the organs in only 17 mice, *i. e.*, in about 8 per cent. So it seems only reasonable to assume that the demonstrated infection with intestinal bacteria after universal radiation is in most of the cases attributable to a direct invasion of the bacteria from the intestinal canal.

Local Abdominal Irradiation of Normal Mice

The above experiment was performed with universal irradiation of the mice, implying radical changes in the functional capacity of the

irradiated organism. It is easy to imagine that an infection originating from the intestinal canal will find a good soil for spreading in an animal after universal irradiation, by which treatment the reticulo-endothelial apparatus and lymphatic tissues besides the nucleated elements of the blood have been damaged severely, if not destroyed altogether.

In order to elucidate whether the general cellular injury causes a decrease in the resistance of the organism to the demonstrated infection with colon bacilli, some experiments were made in which the effect of the Roentgen-rays was limited as far as possible to the intestines alone.

Previously, WARREN & WHIPPLE (1922) (9) have shown that Roentgen-radiation of the thoracic half of the body in dogs with amounts of up to 512 milliampère minutes gives no clinical symptoms of intoxication, whereas a dosage of 320 milliampère minutes applied to the abdominal half of the body in dogs produces violent gastro-intestinal disturbances with fatal outcome.

CORI (1924) (2) found similar conditions in mice exposed to local radiation of the abdomen.

Author's Experiments.

A group of 24 mice were given local radiation with 550 r, applied to the abdomen, to a field of 1×1.5 cm., immediately above the symphysis; the rest of the body was covered by 2 mm. of lead-foil.

Bacteriological autopsy, performed as above, revealed in about half of the animals a moderate infection with colon bacilli, corresponding to the lymphatic apparatus of the intestine, while cultures from the organs and blood of the remaining animals showed no bacterial growth. Thus there was a distinct difference in the occurrence of enterogenous infection in the animals exposed to local abdominal radiation, contrary to the findings after universal radiation.

When the amount of local abdominal radiation was doubled, making a dose of 1 100 r, the bacteriological autopsy showed that the infection with colon bacilli still kept localized to the mesenteric lymph gland in about half of the animals.

There is also a striking difference in the mortality of the irradiated animals in the two groups: 50—80 per cent of the animals exposed to universal radiation with 550 r died »spontaneously», whereas local abdominal radiation with 1,100 r proved fatal to only 4 out of 24 animals.

These findings appear to be in conflict with the findings reported by WARREN & WHIPPLE in experiments with abdominal radiation applied to a variety of animals. But, in their experiments with thoracic and abdominal radiation, these authors divided the body of the animal into two halves by a transversal at the level of the xiphoid process of the

sternum. On abdominal radiation in this manner, the spleen and liver besides a large amount of the circulating blood are exposed directly to the Roentgen-rays, effacing largely the picture of the results from a local radiation that is limited chiefly to the intestines. So the two series of experiments are not commensurable. The abdominal radiation employed by WARREN & WHIPPLE gives similar findings on bacteriological autopsy of the animals as are obtained after universal irradiation.

Effect of Roentgen Rays upon the Reticulo-endothelial Apparatus in the Liver and Spleen

Extensive abdominal irradiation, by which the liver and spleen are exposed directly to the action of Roentgen-rays, differs from local abdominal irradiation by giving rise to the same features of progressive enterogenous infection as is found after universal irradiation. As early as in 1886, WYSSOKOWITSCH (12) demonstrated that the fixed phagocytes (the reticulo-endothelial system) play an important rôle in the organism's combating of bacteriæmia.

ÖRSKOV and collaborators have demonstrated that the fixed phagocytes in the organism, especially those located in the liver and spleen, are capable of phagocytosis of bacteria injected into the blood stream, so that the blood gives no bacterial growth in cultures that are made within a certain length of time after the injection of the bacteria.

On injection of 1 million Breslau bacilli into the blood stream in mice, ÖRSKOV, JENSEN & KOBAYASHI (13) found the blood to be perfectly sterile as soon as 3 hours after the injection, while cultures from the liver and spleen showed growth of Breslau bacilli. This sterile condition of the blood kept for about 20 hours, after which there was again a demonstrable condition of bacteriæmia besides an increase in the number of Breslau colonies in cultures from the liver and spleen.

It seemed reasonable to expect that by employment of the experimental technique given by these authors it might be practicable to settle whether the functional capacity of the reticulo-endothelial apparatus in the liver and spleen is lowered after Roentgen-radiation. It would be natural then for the manifestation of a normal or an altered function to employ the time interval in which the blood is usually sterile in the experimental animals after intravenous injection of Breslau bacilli. If this interval be shortened considerably, or completely absent, in animals with irradiated liver and spleen, it will be reasonable to conclude that the phagocytic power of the reticulo-endothelial system in these animals has been impaired.

The Breslau strain (Br. 206) employed in these experiments has been cultivated numerous »generations» by K. A. JENSEN (5), with incubation

Table II

Controls. Cultures from Normal Animals after Intravenous Injection of 1 Million Breslau Bacilli (in 0.2 c.c. physiol. salt sol.)

Mouse No.	Hrs. after intravenous inj. of bact.	Cervical lymph gl.	Mesenteric lymph gl.	Spleen	Liver	Heart's blood
18	3	+	+	+ + +	+ +	21
19	6	+	+	+ + +	+ +	13
20	6	+	+	+ + +	+ +	6
21	7	+	+	+ + +	+ +	11
22	8	+	+	+ + +	+ +	14
23	10	+	+	+ +	+ +	3
24	10	+	+	+ + +	+ +	10
25	11	+	+	+ + +	+ +	3
26	11	+	+	+ +	+ +	4
27	12	+	+	+ +	+ +	3
28	12	+	+	+ + +	+ +	1
29	15	+	+	+ + +	+ +	29
30	15	+	+	+ + +	+ +	1
31	26	+	+	+ + +	+ +	1
32	50	+	+	+ +	+ +	0
33	72	+	+	+ + +	+ +	0

Table III

Cultures from Radiated Animals after Intravenous Injection of 1 Million Breslau Bacilli (in 0.2 cc. physiol. salt sol.). *Universal radiation* with 450 r. Radiation time: $36^1/_2$ min. Skin target distance: 42 cm. Bacterial injection ca. 72 hours after radiation

Mouse No.	Hrs. after intravenous inj. of bact.	Cervical lymph gl.	Mesenteric lymph gl.	Spleen	Liver	Heart's blood
34	3	+	+	+ + +	+ +	43
35	3	+	+	+ + +	+ +	41
36	6	+	+	+ + +	+ +	23
37	6	+	+	+ + +	+ +	31
38	7	+	+	+ + +	+ +	10
39	7	+	+	+ + +	+ +	31
40	8	+	+ +	+ +	+ +	43
41	8	+	+	+ + +	+ +	14
42	10	+	+	+ + +	+ +	17
43	10	+	+	+ + +	+ +	112
44	11	+	+	+ + +	+ + +	203
45	11	+	+	+ +	+ +	72
46	12	+	+	+ + +	+ +	12
47	12	+	+	+ + +	+ +	20
48	15	+	+	+ + +	+ +	17
49	15	+	+	+ +	+ +	4
50	26	+	+ + +	+ + +	+ + +	51
51	26	+ +	+ +	+ + +	+ + +	75
52	72	+	+	+ +	+ +	37

at a high temperature (46.5° C.); in this way its virulence for mice has been altered so that, when given by mouth in large doses, it produces in mouse an infection that is localized chiefly to the lymphatic apparatus of the intestines.

A group of mice were given universal radiation with 450 r. About 72 hours after this treatment, half of the mice were each given an intravenous injection (into the caudal vein) of 0.2 c.c. physiological salt solution containing 1 million living Breslau bacilli (Br. 206). At the same time, 16 control mice are given intravenously the same dose of living Breslau bacilli (same culture). Bacteriological autopsy is performed on the animals at intervals of one or a few hours, in order to obtain a comprehensive picture of the course of the bacteriæmia in the irradiated animals. In each case the blood culture is made with 20 loopfuls of heart's blood. The number of blue colonies obtained from the 20 streaks in the blood cultures, together with the results obtained in cultures from the organs, are given in Table II.

Table II shows that in the control mice, with one exception (No. 29) the blood became practically sterile in about 12 hours after the bacterial injection. Table III tells an entirely different story about the mice exposed to universal radiation, inasmuch as the heart's blood was not found to be sterile in any of the animals at any time. At the point of time when the blood of the controls was about becoming sterile — that is, 12—15 hours after the bacterial injection — the irradiated animals gave the lowest number of Breslau colonies in the blood cultures, namely: 12, 20, 17, and 4. This might look as if the organism had tried to rid the blood of the injected bacteria. 26 hours after the bacterial injection, however, when the blood of the control was sterile a distinct bacteriæmia could be demonstrated in the animals exposed to universal radiation.

Thus, *universal radiation of mice with 450 r gives a distinctly demonstrable reduction in the power of the mouse organism to filter off from the blood the intravenously injected Breslau bacilli.* This failure is presumably to be attributed chiefly to a change in the functional capacity of the fixed phagocytes in the liver and spleen through the action of the Roentgen-rays. It seemed reasonable to expect that this question might be answered more directly by limiting as far as possible the irradiation to the region of the liver and spleen.

In the following experiment (Table V), each animal is tied down, on its back, to a board by means of a loop of cord around each extremity. The mouse is covered completely by a 2 mm. lead-foil in which there is cut a rectangular hole corresponding to the liver and spleen region. Each mouse is irradiated with 550 r. About 72 hours after the radiation each animal is given an intravenous injection of 1 million Breslau bacilli.

Table IV

Controls. Cultures from Normal Animals after Intravenous Injection of 1 Million Breslau Bacilli (in 0.2 c.c. physiol. salt sol.)

Mouse No.	Hrs. after intravenous inj. of bact.	Cervical lymph gls.	Mesenteric lymph gl.	Spleen	Liver	Heart's blood
53	3	+	+	+ + +	+ +	35
54	3	+	+	+ +	+ +	15
55	6	+	+	+ + +	+ +	11
56	6	+	+	+ + +	+ +	27
57	10	+	+	+ +	+ +	3
58	10	+	+	+ + +	+ +	17
59	12	+	+	+ + +	+ +	2
60	12	+	+	+ +	+ +	1
61	16	+	+	+ + +	+ +	0
62	16	+	+	+ + +	+ +	1
63	24	+	+	+ +	+ +	0
64	24	+	+	+ + +	+ +	0

Table V

Cultures from Radiated Animals after Intravenous Injection of 1 Million Breslau Bacilli (in 0.2 c.c. physiol salt sol.). *Local radiation* with 550 r *applied to the liver and spleen region.* Radiation time: $44^1/_2$ min. Skin target distance: 42 cm. Bacterial injection ca. 72 hours after radiation

Mouse No.	Hrs. after intravenous inj. of bact.	Cervical lymph gls.	Mesenteric lymph gl.	Spleen	Liver	Heart's blood
65	3	+	+	+ + +	+ +	34
66	3	+	+	+ + +	+ +	43
67	6	+	+	+ + +	+ +	37
68	6	+	+	+ + +	+ +	21
69	10	+	+	+ + +	+ + +	85
70	10	+	+	+ + +	+ +	11
71	12	+	+	+ + +	+ +	7
72	12	+	+	+ + +	+ +	35
73	16	+	+	+ +	+ +	1
74	16	+	+	+ + +	+ +	53
75	24	+	+	+ + +	+ +	47
76	24	+	+	+ + +	+ +	11

Then the usual bacteriological autopsy of the controls and the irradiated animals. The findings in the control are entered in Table IV.

This experiment seems to leave no doubt that the phagocytic power of the fixed phagocytes in the liver and spleen is lowered by radiation, as a phenomenon of common occurrence in normal animals fails in this experiment to appear in the radiated animals. If this primary »sterilization» of the blood be actually due to the phagocytic function of these cells, it is to be ex-

pected, reversely, that protection of the liver and spleen in animals exposed to universal radiation may save for the organism its ability to purify the blood after intravenous injection of living bacteria.

In the next experiment a batch of mice are tied down in the usual manner, but a band of 2 mm. lead-foil (2.75 cm. in width) encircles the body of each mouse, corresponding to the liver and spleen region. Each mouse is given radiation with 800 r applied to the free part of the body and the extremities. In this experiment a relatively great dose of Roentgen-rays is given in order to make sure of an extensive destructive effect upon the lymphatic system, the cellular elements in the blood and the bone marrow. These defensive means of the organism will be impaired decisively — if not completely put out of function temporarily — by the intensive radiation here employed. The subsequent intravenous injection of living bacteria will then make particularly heavy, if not absolute, demands on the fixed phagocytes in the liver and spleen.

The bacteriological autopsy shows that the blood in the irradiated mice and in the controls becomes free from bacteria at the same point of time: 16 hours after the injection. This experiment demonstrates plainly how decisively important is the rôle played by the fixed phagocytes of the liver and spleen when the organism has to combat an infection. Here the experimental animals have been exposed to a dose of Roentgen-rays that is known by experience to destroy numerous cells, the function of which is, partly or entirely, to assist the organism in combating the infection. Yet, on subsequent intravenous injection of 1 million Breslau bacilli (Br. 206) the organism of such an animal is able to rid the blood stream of bacteria — and do it just as quickly as the controls. *From this it seems justified to conclude that the phagocytosis performed by the reticulo-endothelial apparatus of the liver and spleen is of decisive importance to the organism in its combating of infection.*

The Kupffer cells of the liver are said to furnish a classical example of fixed cells with a pronounced power of phagocytosis. It might prove of interest then to investigate how big a part these cells take in the purification of the blood after intravenous injection of bacteria. Naturally one would expect to throw some light on this question by applying local radiation to the liver region alone, giving the animal a subsequent intravenous injection of bacteria and performing bacteriological autopsy in the usual manner. It is to be kept in mind, however, that it is difficult to expose the liver to radiation without secondary involvement of the spleen, especially in such a little animal as the mouse.

A batch of mice are tied down in the usual manner. Each mouse is covered by a 2 mm. lead-foil in which is cut a rectangular hole, corresponding to the liver region, measuring 1.5 cm. longitudinally and extending barely 0.5 cm. to the left of the midline of the mouse.

Each mouse is radiated with 550 r; about 72 hours later it is given an intravenous injection of 1 million Breslau bacilli (Br. 206) suspended in 0.2 c.c. physiological salt solution, into the caudal vein.

As in the preceding experiments, the bacteriological autopsy showed the blood of the controls to be free from bacteria as early as 16 hours after the injection. In the radiating animals, on the other hand, the blood became in no instance sterile with a period of from 4 to 24 hours after the injection. Two animals were autopsied 4 hours after the injection, the next pair 16 hours after the injection, and the remaining three pairs respectively 20, 22, and 24 hours after the injection; the number of colonies in the blood cultures were respectively 5, 135, 12, 7, 3, 66, 56, 10, 75 and 4. The radiated group showed wide variations, however, in the number of colonies obtained from the heart's blood, something that may presumably be attributable to the afore-mentioned difficulty of applying radiation to one organ alone in such small animals.

On autopsy, the radiated animals showed a moderate decrease in the size of the spleen, but in no instance such extreme degrees of atrophy of the spleen as would appear after direct radiation of the spleen with the dosage here employed.

Two of the mice showed macroscopic changes in the liver. One presented a distinct enlargement of the liver with typical nutmeg-pattern on the surface and on section. In another the liver was enlarged too, but pale yellowish in colour, without any structural pattern, more suggestive of fatty degeneration.

Judging from the findings in this experiment, the Kupffer cells of the liver play an important rôle in the organism's purification of the blood stream after bacterial invasion.

Histological Examination of the Intestines in Mice after Universal Irradiation, with Special Reference to the Occurrence of Bacteria in the Tissues

WARREN & WHIPPLE (1922) (9) have examined histologically the intestines of dogs that had been exposed to abdominal radiation with doses from 350 to 480 milliampère minutes (Coolidge tube, from 85 to 103 kilovolts, skin target distance of 25.4 cm., 2 mm. sheet aluminum filter) and found pronounced changes in the epithelial covering of the villi and crypts of the small intestine from the pylorus to the ileocoecal valve. The authors had the impression that the epithelial cells of the crypts are the least resistant as these cells were the first to show signs of degeneration and beginning necrosis, but also numerous villi were practically denuded as early as 3 days after the radiation. It is mentioned that the loops of the small intestine contained a large amount of mucus.

The colon showed only very slight changes, appearing especially as an increased number of goblet cells.

In subsequent studies, reported in 1923, the same authors (11) employed the Gram-method for staining bacteria in fixed sections from the intestines, and found numerous bacteria, in particular Gram-positive rods, between the villi and in the crypts of the jejunum and ileum. In the markedly injured areas, masses of bacteria were lodged among the disintegrated epithelial cells and up against the basement membrane where the epithelial cells had fallen away. At no place were any bacteria found to have invaded the stroma, and there was no evidence of local bacterial invasion at any point. Bacteria were not observed in the few leucocytes present in the tissues.

MOTTRAM & KINGSBURY (1924) (8) think that the presence of intestinal bacteria in the blood stream in animals that have been exposed to universal Roentgen radiation is dependent upon a break in the continuity of the intestinal mucosa. The radiation gives rise to an increased production of mucous, especially in the small intestine, so that bacteria here come mechanically in intimate contact with the epithelial cells, invade the crypts and empty goblet cells and thus gain entrance into the lymph spaces and capillaries of the submucosa.

Author's Findings:

In my own studies on changes in the intestinal epithelium after Roentgen radiation the main stress is laid upon the relation of the bacteria to the intestinal mucosa, aiming in the first place to obtain information about the way in which the bacteria gain entrance from the lumen of the intestine into the lymphatics.

A batch of mice are exposed to universal radiation with 700 r (skin target distance of 32 cm., radiation period of 33 minutes). Even as early as 3 days after the radiation two of the mice sit crouching in a corner of the cage, their fur a-bristling. These two animals and four more are killed on that day, and bacteriological autopsy is performed in the usual manner, with cultures from the mesenteric lymph gland, cervical lymph glands, liver and heart's blood. In addition, blocks of tissue were taken from the liver, spleen and various parts of the intestines and fixed for histologic-bacteriological examination.

The same procedure was repeated on the next day, and 6 and 8 days after the radiation. The cultural results were of similar character and distribution as shown in Table I.

The tissue blocks for microscopic examination are fixed after the following method:

Saturated watery solution of sublimate	5 parts	about 12 hours.
Alcohol 93 %	4 »	
Formaldehyde 35 %	1 part	
Wash in running water	ca. 12	»
Alcohol 70 %	2—8	»
Iodine-alcohol 70 %	2—8	»
Alcohol 70 %	2—8	»
Alcohol 93 %, I	2—8	»
Alcohol 93 %, II	2—8	»
Absolute alcohol, I	2—8	»
Absolute alcohol, II	2—8	»
Ligroin, I	2—8	»
Ligroin, II	2—8	»

Imbedding in paraffin.

The sections are stained after 3 different methods:

I. Iron-hæmatoxylin (VAN GIESON).
II. Hæmatoxylin-eosin (HANSEN).
III. Special staining of bacteria in tissues (method given by B. VIMTRUP) as follows:
After removal of paraffin, the sections are placed in a
1 % chromium alum-gallocyanin solution for 48 hours. Then in
1 % alcoholic safranin sol. for 3—4 hours.
Wash in water. Then in
1 % methyl green sol. for 1—5 minutes.
Wash in water.
Blot with filter paper.
Rapid dehydration, and differentiation with abs. alcohol.
Xylol.

Histological Examination

The histological examination of various parts of the intestinal tract in mice that are killed from 3 to 8 days after universal radiation shows some changes in the epithelial lining of the small intestine, the cell borders being indistinct and the nuclei appearing to stain more faintly than normally. In sections from mice that are killed 7—8 days after the radiation, mitotic figures appear more frequent than normally. There is more mucus in the intestinal lumen and in the crypts than is found under normal conditions. In some areas the epithelium is very low, with a strikingly small amount of protoplasm; this is seen especially on the villi, but there is no evidence of necrosis or desquamation of the epithelium. No lymphoid tissue is seen at any point.

The ileocoecal part presents the same changes in the epithelium as described above, but less pronounced. Here, too, there seems to be more mucus in the intestinal lumen and in the crypts than is usually seen under normal conditions.

In the colon the epithelial cells appear not to have undergone any demonstrable histological changes after the radiation. The number of goblet cells appears normal.

The liver cells are not so distinctly defined as normally. There seems to be an increase in the number of nuclei, but they are under normal size. There is an increase in the number of mitotic figures. No leucocytes or lymphocytes are seen in blood vessels or tissue spaces.

The spleen is markedly atrophic, showing a striking disintegration of the follicles.

Bacteriologic-histological examination

On examination of sections from a normal mouse that are stained with a special view to the presence of bacteria, the intestinal contents show masses of rod-shaped particles, varying greatly in length and thickness. Judging from their morphology, these particles certainly appear to be the rod-shaped bacteria normally present in the intestines. These particles can be demonstrated in the lumen of the small intestine and especially in the intestinal contents in the ileocoecal part of the gut, where they are found in large amounts. The particles (bacteria) are found to be localized to the intestinal lumen, and are seen but seldom in close contact with the epithelial cells corresponding to the »surface». Only in one spot are such rod-shaped particles demonstrable in the crypts.

On examination of sections from the intestines of irradiated mice, stained after the special method for bacterial staining, they are found to differ distinctly from the normal picture. Here the rod-shaped particles (bacteria) are found to be in intimate contact with the mucous membrane of the ileocoecal part of the gut, where they are seen even as dense masses in many of the crypts.

Also sections from the jejunum and ileum show rod-shaped particles in immediate contact with the mucous membrane, but only in one case, are such particles found in the crypts.

None of the sections from the colon show rod-shaped particles in the crypts.

On more close examination of the epithelium cells in those areas where the road-shaped particles are in intimate contact with the cells, it is practicable to demonstrate such rod-shaped particles of varying length located within the cells at varying distance from the nuclei, also on the basal side of the nuclei; in a few places, bodies of similar morphology

are located basally to the epithelial cells, between the connective tissue cells of the submucosa.

Sections from 8 of the mice show rod-shaped particles in the crypts in the ileocoecal part of the gut, but such particles are not demonstrable in the crypts in the other parts of the gut except, as mentioned above, in one case.

In 4 cases rod-shaped particles were found in the epithelial cells or basally to these cells in sections from the ileocoecal part of the gut.

By means of the staining method given by VIMTRUP, it has thus been possible in sections from the intestines of mice to demonstrate the presence of rod-shaped particles which suggest by their form, varying length and location, that they are most probably bacteria (colon bacilli). In normal mice such particles may be demonstrated only in the intestinal contents in sections from the gut. In sections from mice which have been exposed to universal radiation, such particles are demonstrated not only in the intestinal contents but also in intestinal crypts and epithelial cells. In the material here examined the presence of the rod-shaped particles (bacteria) in the epithelial cells is found most often in sections from the ileocoecal part of the gut, whereas this phenomenon is seen in the jejunum only in one case, and not at all in the colon.

The questions then arise: Why do the intestinal epithelial cells become permeable to bacteria? and: Why are the epithelial cells in the ileocoecal part of the gut apparently the least resistant? These questions naturally suggest themselves after the findings above, but if we try to give an explanation of the mechanism of this »bacterial permeation», it can only be entirely hypothetical. Yet the following conditions may be pointed out in this connection.

In many cases, and especially those in which the bacteriæmia is demonstrated, the intestines are found to be whitish yellow, dilated with a large amount of thin and partly mucoid contents, here and there distended with air. At this stage, undoubtedly, the peristalsis must have been lowered, implying the possibility for processes of bacterial decomposition and lively bacterial growth. Owing to the abundant, partly mucoid, fluid contents in the gut, besides the slow transport of the intestinal contents, the entirely mechanical conditions are very favourable for the establishment of intimate contact between the bacteria and the intestinal mucosa. If, further, the bacteria are lodged in contact with cells of altered or lowered functional capacity, this will give favourable conditions for the bacteria to grow through the mucous membrane. It does not seem very likely to assume that the capacity of the bacteria for penetration into and through the epithelial cells would be dependent primarily upon the bacterial power of active motility, as previous experiments by

the author (1) have shown that non-motile bacteria, *e. g.* pneumococci, are able to penetrate the intestinal mucosa.

Is there any further difference between epithelial cells containing rod-shaped particles and other epithelial cells as seen in the same field? On histological examination, as mentioned before, the more pronounced signs of degeneration after universal radiation are found in the epithelium of the jejunum and ileum, something that seems rather strange in view of the fact that the »bacterial permeation» is demonstrated most frequently in the ileocoecal part. On comparison of the cellular properties — shape, definition of borders, staining qualities, size and form of the nuclei — found in the cells which contain rod-shaped particles and in neighbouring cells without any such particles, there is found no demonstrable difference, so that it is impossible from the appearance of a cell to estimate its ability to keep bacterially intact. There is nothing left then but to explain this phenomenon as dependent upon an altered or lowered functional capacity of the cell, something which seems the more probable when we keep in mind that Roentgen-rays given in the doses here employed are able to lower or destroy the functional capacity of some cells and tissues.

Once the bacteria have made their way through the epithelial cells and gained entrance into the lymph spaces, they find here more favourable conditions for continued growth and further invasion, as the number of free phagocytes in the organism is greatly reduced after universal radiation.

These examinations and appertaining considerations are far from settling the question of the way and manner in which the intestinal bacteria gain entrance from the intestinal lumen into the lymph spaces of the intestinal wall. Yet, *these studies have shown that epitelial cells in the intestine may be made permeable to bacteria by the action of an external agent;* and it may be that further knowledge of the metabolism and function of the individual cell turns out to be the road by which we may reach to a solution of this problem which is so important in the pathogenesis of many infectious diseases.

Is the Radiation Effect upon the Intestinal Epithelium Direct or Indirect?

As mentioned before, after local abdominal radiation applied to a field of 1 × 1.5 cm., the usual bacteriological autopsy yielded only a strikingly slight growth in cultures made from the organs at a point of time when it would be reasonable from previous experiences to expect even an abundant bacterial growth. The validity of this finding was ascertained by repeated duplicate experiments, with similar results even when a

relatively large dose of Roentgen-rays was employed (1,100 r). How is this finding to be interpreted? Does it mean that the Roentgen-rays do not directly injure the intestinal epithelium, and that universal radiation, causing impairment of the fixed phagocytes with cellular disintegration resulting in the production of toxic substances, brings about an intoxication of the organism, which in turn alters the functional capacity of the intestinal epithelial cells? In other words: Is the radiation effect upon the intestinal epithelium an indirect effect of the Roentgen-rays?

To throw some light on this question, the following experiments are carried out:

6 mice are tied down in the usual way, lying on their back. Each animal is covered by a 2 mm. lead-foil in which there is cut a rectangular hole, measuring 1 × 1.5 cm., and exposing a part of the abdomen — from the symphysis to 1 cm. above, and ¾ cm. on both sides of the midline — to direct radiation. The dose is 700 r (radiation period of 33 min., skin target distance of 32 cm.).

One mouse is found dead on the 5th day after the radiation; the bacteriological autopsy shows abundant growth of Bac. coli in cultures from the liver and blood. The bacteriological autopsy of the remaining 5 mice (L1—5) gave the following results: L1 and L2 were autopsied 5 days after the radiation; L1 yielded growth of Bac. coli in cultures from the mesenteric lymph gland, spleen and liver, whereas L2 gave bacterial growth only in cultures from the mesenteric lymph gland. L3 was autopsied 6 days after the radiation and gave scanty growth of Bac. coli in cultures from the mesenteric lymph gland, spleen and liver. L4 and L5 were autopsied 7 days after the radiation, and they both showed sterile organs and blood.

In each case blocks of tissue are taken from the liver, spleen and various parts of the intestines for histological examination. The tissues are fixed and stained after the methods given above (p. 652).

None of these animals showed any sign of illness at the time it was killed. The macroscopic autopsy findings are as follows:

L. 1 shows marked injection of the ileocoecal part of the gut and of the adjacent part of the ileum, but no oedema or sign of ulceration. The spleen appears to be of normal size. The mesenteric lymph gland is markedly atrophic.

L. 2 shows slight injection of the ileocoecal part of the gut and marked atrophy of the mesenteric lymph gland, but no other abnormalities.

L. 3 and L. 5 show no abnormalities except for atrophy of the mesenteric lymph gland.

L. 4: The loops of the small intestine are whitish yellow in colour and somewhat distended by gas-producing fluid material.

Another batch of 6 mice are irradiated at the same time, in the same manner and with the same dose of Roentgen-rays. Of these ainmals, 1 dies 4 days after the radiation, and cultures from the organs and heart's blood give growth of Bac. coli, while 1 mouse dies 7 days after the radiation, giving likewise growth of Bac. coli in cultures from the organs and heart's blood. The remaining 4 mice survive and are killed 28 days after the radiation; the autopsy reveals no abnormalities in these four animals, and cultures from the organs and heart's blood show no bacterial growth.

Microscopic examination of intestinal sections from the L. mice, stained for demonstration of bacteria, shows similar features in L. 1, L. 3, L. 4 and L. 5 as are described above in mice exposed to universal radiation: In L. 1 and L. 3 there are numerous rod-shaped particles (bacteria) in the crypts in the ileocoecal part of the gut, and in one area such particles are found inside the epithelial cells too. In L. 4 and L. 5 a great many crypts are crowded with »shoals» of rod-shaped particles, but these elements are not found inside the epithelial cells at any point.

So there is no particular difference in the histologic-bacteriological picture of the intestines after universal radiation and after local radiation. It seems reasonable, therefore, to assume that *the permeability of the intestinal epithelium to bacteria is due to a direct effect of the Roentgen-rays.*

On the other hand, there is a conspicuous difference in the cultural findings after universal radiation and after local abdominal radiation (applied to the intestines). This difference is presumably due to the fact that the various defensive means of the organism are injured directly by the Roentgen-rays on exposure of the animal to universal radiation whereas local abdominal radiation (applied to the distal part of the abdomen) leaves a serviceable defensive apparatus available to the organism, the fixed phagocytes of the liver and spleen being capable of function, and leucocytes and antibodies may be mobilized and brought into action. This, probably, is the cause of the difference in the course of the enterogenous infection in the two groups of experimental animals. At any rate, it seems justified to conclude that the radiation effect upon the intestinal epithelium is a direct effect of the Roentgen-rays.

On the Cause of »Roentgen Death» in Experimental Animals

As early as 1903, HEINIKE (4) reported that when mice are exposed to universal Roentgen radiation for more than 5 hours they die in from 3 to 11 days after the radiation. He did not think he was able to give any satisfactory explanation of the cause of death. In experiments with guinea-pigs he also observed a fatal outcome when the exposure to universal radiation was extended over a certain length of time.

MEYER & RITTER (1928) (7) advocated that this constantly occurring »Roentgen death» in mice after universal radiation might be utilized in the working-out of a biological standard dose of Roentgen-rays.

FABRICIUS-MÖLLER (1928) (3) has demonstrated the frequency of hæmorrhagic diathesis of thrombopenic nature in guinea-pigs after universal radiation, and he looks upon this tendency to hæmorrhages into the organs as the cause of »Roentgen death» in these animals.

The fact that commonly employed experimental animals succumb within 14 days after universal radiation with a suitable dose of Roentgen-rays has thus been recognized since the earliest days of roentgenologic biology, and there is no concensus of opinion as to and adequate causal explanation of the phenomenon.

It has been pointed out that these animals have shortly before death a marked degre of anæmia. Whether this anæmia be attributable to hæmorrhages in the organs on account of acquired hæmorrhagic diathesis or the cause may be found in destructive injury to the hæmatopoietic system, there can be no doubt that universal radiation with lethal doses of Roentgen-rays often produces a very marked degree of anæmia.

WARREN & WHIPPLE (11) are inclined to think that the universal intoxication of the organism is the cause of death, as a marked increase in the disintegration of cells together with abnormal conditions of absorption from the intestinal canal will flood the organism with more or less toxic substances. These authors, as mentioned before, have shown that abdominal radiation is directly injurious to the organism, while the animals are able to survive thoracic radiation with the same or even greatly increased doses of Roentgen-rays.

Thus, it is yet an unsettled question why the experimental animals die after exposure to universal radiation or to extensive abdominal radiation. The experimental studies here presented are not claimed to solve this question, nor were they planned to do so. But the histo-bacteriological examination of numerous sections from the animals here employed has afforded again and again an occasion to take this question into consideration. The present observations appear to suggest that the »Roentgen death» in these animals is ascribable to the interaction of several vitally destructive agencies arising from functional changes in various tissues of the organism.

The bacteriological autopsy of moribund mice that have been exposed to universal radiation shows frequently an easily recognizable and often violent degree of bacteriæmia. A pronounced degree of anæmia appears to be of frequent occurrence in these animals, but in some of the cases there was clinically no reason to assume the presence of anæmia. In one case, on the other hand, the animal died with a severe degree of anæmia and without any infection of the organs and blood stream. Finally, one

animal was moribund without any distinct anæmia and without any infection whatever.

These observations give one the impression that *the cause of the well-known »Roentgen death» in ordinary experimental animals is to be looked for in a combination of several concurrent destructive agencies, including anæmia, intoxication and enterogenous bacteriæmia. But in most cases it will be impossible to say which of these agencies has been the more decisive of the fatal outcome.*

SUMMARY

After universal radiation of normal mice with Roentgen-ray doses from 250 r to 550 r, the bacteriological autopsy of the animals in 3—10 days after the radiation shows the presence of an infection of the organs and heart's blood with bacteria which are normally present in the intestinal canal in mice. Local radiation, limited chiefly to the intestines, with Roentgen-ray doses up to 1,100 r does not give rise to a progressive enterogenous infection. Radiation of the entire abdomen, exposing the liver and spleen to direct radiation, with suitable doses of Roentgen-rays gives rise to a progressive bacteriæmia.

Mention is made of an experimental technique employed here to study the rôle played by the reticulo-endothelial apparatus in the liver and spleen of the mouse in combating infection of the blood stream with Breslau bacilli.

Histological-bacteriological examination is made of sections from the intestines of mice exposed to universal radiation. The writer thinks he has observed that the epithelial cells of the intestines in mice, corresponding in particular to the ileocoecal part of the gut, after radiation may lose the ability to retain the bacteria normally present in the intestinal lumen.

ZUSAMMENFASSUNG

Nach allgemeiner Bestrahlung normaler Mäuse mit Röntgenstrahlen in Dosen zwischen 250 r und 550 r erwies die bakteriologische Autopsie der Tiere 3—10 Tage nach der Bestrahlung das Vorhandensein einer Infektion der Organe und des Herzblutes mit Bakterien, die normalerweise im Darmkanal von Mäusen vorkommen. Lokale, hauptsächlich auf die Eingeweide beschränkte Bestrahlung mit Röntgenstrahlen in Dosen bis 1100 *r* bewirkt keine progressive enterogene Infektion. Bestrahlung des ganzen Abdomens, wobei Leber und Milz direkter Bestrahlung mit Röntgenstrahlen in geeigneten Dosen ausgesetzt werden, ruft eine progressive Bakteriämie hervor.

Verf. bespricht eine experimentelle Technik, die hier zur Anwendung kam, um die Rolle zu studieren, die der retikuloendotheliale Apparat der Leber und Milz der Maus bei Bekämpfung der Infektion des Blutstroms mit Breslau-Bazillen spielt.

Verf. unterzog Schnitte aus Eingeweiden universal bestrahlter Mäuse histologisch-bakteriologischer Untersuchung und glaubt beobachtet zu haben, dass die Epithelzellen der Eingeweide der Mäuse hauptsächlich im ileozökalen Teil des Darmkanals nach Bestrahlung die Fähigkeit verlieren, die normalerweise im Darmlumen vorhandenen Bakterien zurückzuhalten.

RÉSUMÉ

Après une irradiation universelle de souris normales, avec des doses de rayons X de 250 r à 550 r, l'autopsie bactériologique montre, 3 à 10 jours après l'irradiation, la présence d'une infection des organes et du sang du cœur avec des bactéries normalement présentes dans l'intestin des souris. L'irradiation locale, limitée principalement à l'intestin, avec des doses de rayons X jusqu'à 1100 r ne donne pas naissance à une infection entérogène. L'irradiation de l'abdomen en entier, exposant le foie et la rate à une irradiation directe, avec des doses convenables de rayons X donne naissance à une bactériémie progressive.

Il est fait mention d'une technique expérimentale employée ici pour étudier le rôle joué par l'appareil réticulo-endothélial du foie et de la rate de la souris dans la lutte contre l'infection du sang par le bacille de Breslau.

Il est fait un examen histologique et bactériologique de coupes des intestins des souris universellement irradiées. L'auteur pense avoir observé que les cellules épithéliales de l'intestin des souris, en particulier celles qui correspondent à la partie iléo-caecale, peuvent perdre leur faculté de retenir la bactérie normalement présente dans la lumière intestinale.

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FROM THE MEDICAL CLINIC II OF THE SERAPHIMER HOSPITAL, STOCKHOLM.
PHYSICIAN-IN-CHIEF: PROFESSOR H. C. JACOBÆUS

CASE OF SEVERE BULLOUS EMPHYSEMA[1]

by

H. C. Jacobæus

(Tabulæ LXXXIX—XC)

The following case, on account of its rarity and the difficulty encountered in its diagnosis, offers so much interest that it seems to me to merit a short description.

The case is that of a man, aged 48, with the following clinical history. Family history nil of importance. No known exposure to tuberculosis. Beyond the ordinary diseases of childhood he has on the whole enjoyed good health; lues denied. In 1928 right-sided pneumonia without complications. Has never been troubled with any shortness of breath and has managed a fairly heavy work without any difficulty. On June 20, 1930 the patient while at work sustained a blow from a cart-shaft on the left anterior part of the chest at the level of the costal arch. He did not faint and was able to continue with his work but felt some pain on moving and on taking deep breaths. No coughing of blood. Gradually the pains disappeared and after a month he was quite well again.

At the end of August patient began to be troubled with shortness of breath during work and on mounting stairs. No pains and no stitch in the side. As symptoms gradually became worse the patient sought advice in Sept. 1931 at S:t Göran's Hospital from the records of which the following data have been collected. Roentgen ex. Sept. 16, 1931: left-sided pneumothorax. A flap of the upper lobe is lightly adherent to the thoracic wall at the level of I. 2. A flap of the lower lobe is also adherent below to the diaphragm and the chest wall. This flap shows much greater air-contents with a delicate and thin lung structure. The right lung shows well-marked emphysema within its basal parts. Within its upper parts the lung design is better marked than is normally the case, a broom-like peribronchial opacity being apparent around the central bronchi. (Fig. 1 shows accuratly the same picture little more advanced 3 years later.)

Condition Sept. 18, 1931. — General condition good. Moderate dyspnoea. Over the right lung in front there is dulness from the supracl. fossa to C. 3 where expiration is prolonged; no râles. Over the left lung hypersonorous percussion note, breathsounds inaudible. Ictus faintly heard in I. 5 in the mammary line. Sputa yellow-green mucoid, no tbc. bac. WR neg. Otherwise nil. On Sept. 19, 1931 the pressure in both pleurae was measured by double manometers: »Both columns follow each other accurately all the time, the left being all the time 6 cm. higher than the right». The pressure difference is

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practically speaking the same in all the respiratory phases. Exsufflation of 300 cc. from the left side.

Ordinary breathing r. side pr. — 0.4 — 8.6; l. side + 5.4 — 2.8
Deep » r. side pr. — 0.5 — 0.7; l. side + 7.3 — 4.8

On ordinary respiration the pressure difference between the right and left side is the same, 5.8 during inspiration and expiration. On deep breathing the difference is 7.3 during expiration and 4.9 during inspiration.

Roentgen ex. Sept. 19. — The pneumothorax more extensive on the left side and the lung more compressed than before. The external outline of the lung is well demarcated from the pneumothorax cavity (Fig. 2).

$^{21}/_{9}$. — Pressure + 5.6 + 1, exsuffl. 700 cc.: pressure — 3.6 — 7.9
$^{22}/_{9}$. — » + 9.0 — 1, » 2,000 cc.: » + 1.0 — 11.0

Exsufflation of gas, 1,000 — 2,000 cc., was then repeatedly made with but temporary effect.

Nov. 3, 1931 patient discharged for observation at Out-patient's.

Jan. 18, 1933 readmitted. On the whole the same clinical findings as when last in hospital.

Roentgen ex. Jan. 20, 1933. — Complete pneumothorax on the left side. Exsufflation on Feb. 2, 4, 6, 9, 11, 1,000—1,350 cc. at a time, with the same temporary effect as when last in hospital. His condition has since then remained the same. Patient admitted Oct. 19, 1934 for observation.

Condition on adm. — General condition good. Physical development ordinary. Coverings and muscular development ordinary. Slight dyspnoea and lip cyanosis. Over the greater part of the left lung there is a hypersonorous to tympanitic note with exceedingly faint breathing which is even absent in some places, particularly in front. No râles.

Roentgen ex. — Left-sided pneumothorax. Displacement of heart and mediastinum to the right. The upper parts of the lung are widely adherent in front. There are no visible indurations in the right lung (Fig. 1). *Heart.* — Ictus not palpable. Impossible to determine cardiac outlines by percussion. Sounds clear though somewhat dull, best heard over the sternum and to the right of this. No accentuation. Rhythm regular. Bl. pr. 135/90 mm. *Blood.* — Hgb 101 %, red bl. corp. 4.9 mill., white 8,000. Other organs normal.

Oct. 24. — Sputum white and mucoid. Nil tbc. bac.

Oct. 25. — On thoracoscopy an exceedingly peculiar picture was obtained. Nowhere on the lung, diaphragm or parietal wall did the respective pleura present a normal appearance. The lung surface was greyish, slate-coloured and shiny with a peculiarly thready sort of appearance. No serous membrane visible in the ordinary way. Where the lung is lying closer to the chestwall there is a whole lot of fine fibres passing between the lung and the chestwall, undoubtedly more delicate than the finest adhesions commonly seen in pneumothorax. In addition blood-vessels are seen even in very fine fibres. (Text Fig. 1). No bronchial lumina could be seen on the parts facing the hilum. On those parts of the parietal wall where one would expect to find a normal pleura parietalis the usual appearance of ribs and interspaces are not met with; the surface is not so smooth and shiny and everywhere small groups of coal pigments are dotted about (Text. Fig. 2). Above towards the apex there is a light-coloured area with distinct respiratory movements. This is obviously a more normal part of the lung. There is no doubt that the thoracoscopy was carried out in a cavitation within the lung, viz. in an enormously large emphysematous cavity.

The patient experienced no discomforts whatever after the thoracoscopy (Fig. 3 shows only a little pneumothorax at the base of the lung after the op.)

Nov. 1.— Bronchography with lipiodol. When the patient is sitting upright the opaque agent only passes down into the right main bronchus, mainly collecting into the bronchi of the lower lobe. These bronchi show no evidence of any pathological changes. Some lipiodol runs out into the alveoli which seem to be dilated. On putting the patient on his left side the bronchi of the left lung also become filled with lipiodol. The branches of the upper lobe present a normal appearance. The bronchi of the lower lobe are displaced forwards and much thinner than corresponding bronchi on the right sides. Close to the main bronchus the bronchial branch to the lower lobe measures scarcely half as much as the corresponding branch on the right side. On the right side we get numerous bronchial branches passing backwards filled with lipiodol. Corresponding branches on the left side cannot be seen. None of the opaque agent has passed out into the emphysematous cavity of the lung. Since the previous examination a narrow strip of pneumothorax has been added on the left side (Fig. 4).

Fig. 1.

Nov. 2. 1934. — Twenty-four hours after the lipiodol injection there is a slight amount left in the base of the right lung. It is only right at the base of the inner part of the left lower lobe that some streak-shaped remnants of the lung structure can be seen. Besides that it is quite obliterated.

Jan. 10. 1935. — On the left side a pneumothorax cavity is still present. The much expanded and emphysematous lung flaps stand out well against the pneumothorax cavity. There is considerable displacement of heart and mediastinum to the right side. The emphysema in the basal and lateral parts of the right lung has increased. Some remainder of the lipiodol can be seen in the right lung.

Fig. 2.

Comments. — In a case of such great rarity as the present one it is in the first place the diagnosis round which the interest is drawn; as is evidenced by the description of the case this was wrongly diagnosed in both

clinics at the examination of the patient. If we first pay attention to the history it is of interest to note here that the patient sustained quite a severe blow to the left chestwall, thus the very side where the bullous emphysema was located. It is uncertain whether there ever was any rib fractured. He did not even have to interrupt his work. A few months later the first symptoms of his condition commenced in the form of increasing shortness of breath on mounting stairs and on exertion. In other published cases I have been unable to find trauma mentioned as cause of the disease in question. For my own part I find it very difficult to understand in what way a trauma of that nature might have brought on a diseased process of that kind. Furthermore if we compare the radiograms taken at this early date with those taken 4 years later the difference is very slight. In my view this is in favour of the disease being of a much older date. At the clinical examinations undertaken after his admission to various hospitals the findings observed were quite similar on the three different occasions at twelve months interval or more.

There was the typical appearance of a pneumothorax with weakened to absent breathing and a hypersonorous note. The roentgen appearance was such as to cause one to assume an incomplete pneumothorax with numerous fine adhesions in the upper and lower part of the pleural cavity and above and below respiring parenchyma (Fig. 1).

On the previous occasions of the patient's stay at S:t Göran's Hospital his pneumothorax had been explored and large quantities of air removed. One must strictly distinguish here between the first exploration and all the others. At the first exploration one undoubtedly entered the emphysematous cavity in the lung. The pressure was simultaneously measured in the pleura on the one side and in the emphysematous cavity on the other, the latter pressure being found to lie 6—7 mm. H_2O higher than the former. During expiration the pressure was quite appreciably positive. There obviously existed some valvular mechanism between the emphysematous cavity and the bronchi.

The second roentgen examination after this first exploration gave quite a different appearance. One then had an obvious pneumothorax, the lung being considerably emphysematic; the large emphysematous cavity in the lung was clearly in evidence (Fig. 2). The contour of the lung itself looked like a thin bent line, within which there is no visible lung structure except above and below and at the hilum. This appearance would seem to be characteristic when the lung is the seat of a bullous emphysema. All subsequent exsufflations were most probably made from the pleura and not from the bullous emphysema. A stab pneumothorax has been present where healing of the sinus was exceedingly slow on account of peculiar circumstances; this caused the pneumothorax to become an extremely prolonged affair. At the exsufflations carried out at times

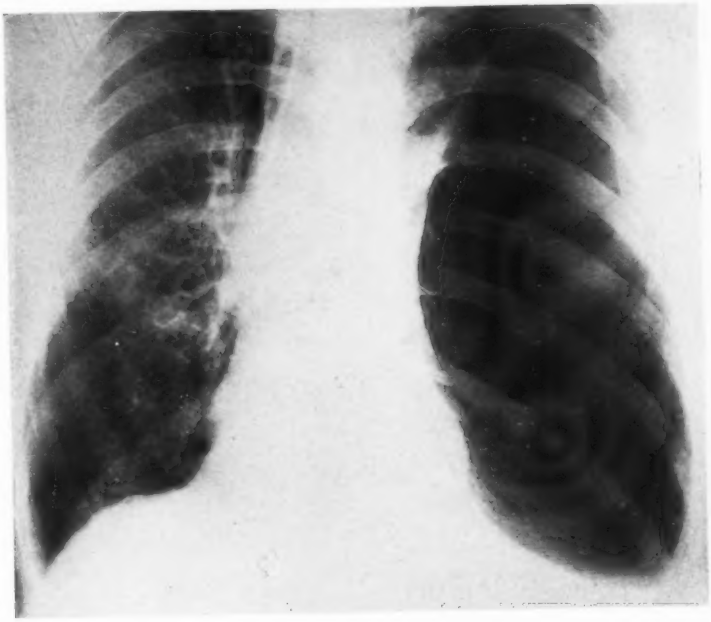

Fig. 1.

Fig. 2.

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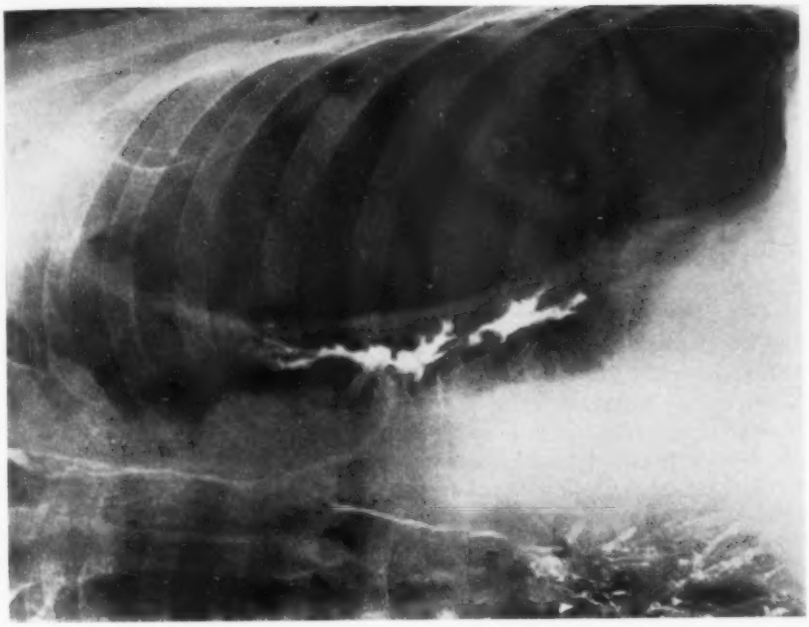

Fig. 4.

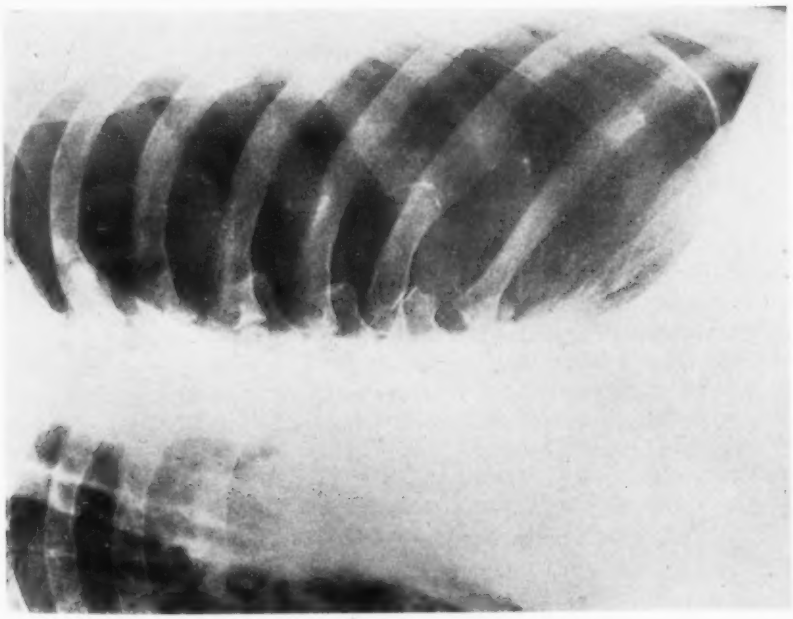

Fig. 3.

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every or every other day an exceedingly slight effect was obtained in spite of such large exsufflations as over one litre. Only a temporary increase of the negative pressure was obtained. All these experiments go to show that communication existed with the bronchi via the emphysematous cavity although it was fairly small; it was sufficient, however, temporarily to lower the pressure and in part to expand the lung.

On admission to the Seraphimer Hospital similar conditions were found, as already mentioned, as on previous admissions to hospitals. The same diagnostic error was made here as before. The case was simply regarded as a chronic spontaneous pneumothorax. In order to examine the possibilities for treatment by cauterization of adhesions an expedient thoracoscopy was carried out by the author. On introducing the trocar nothing unusual was noticed. Thoracoscopy on the other hand gave the greatest surprise. The reader is referred to the description already given. From this it is clearly obvious that one had entered a cavity within the lung, the appearance of which is probably very typical. There was no visible pleural membrane. The lung itself had the same colour as a collapsed lung but its surface had a peculiarly stringy kind of structure. It had the appearance one expects to find in a collapsed normal lung after the pleura has been peeled off. No bronchial openings were seen towards the hilum. On a previous occasion I had been able to examine by the thoracoscope a tuberculous cavity of enormous size and it was then exceedingly easy to see numerous bronchial openings partly filled with a purulent secretion. Another thing that struck one in this case was the complete absence of any inflammatory element in the diseased process.

It is further of great interest to study the walls of the cavity because of the great accumulation of fine threads being in evidence here. These fibres are longest in the centre of the cavity and become shorter peripherally at the same time as becoming much more numerous. In many of them can be seen very delicate blood-vessels. They are thinner and more transparent and much more numerous than the pleuritic adhesions observed in the ordinary artificial pneumothorax. There is no doubt that these formations are remnants from the alveolar walls. I think from this appearance we can form a certain impression of the progress of the process. As a result of a valvular effect we get a positive pressure in such an emphysematous cavity. Together with the blood-vessels these fibres are subjected to a certain amount of stretching; finally the blood-vessels become obliterated and the fibres severed whereby we get a very slow increase in size of the emphysematous cavity, a process therefore analogous with the spontaneous rupture of the finest adhesions in pneumothorax. From this it also follows that the boundary of the radiogram is exceedingly diffuse towards the periphery. From this appearance it is evident in this case that the condition above all has the character of some damage

to the parenchyma, a disappearance of the alveolar wall. This does not of course exclude the possibility of some affection of the bronchi being the primary cause of disease. For my own part I would not venture an opinion about this.

As in a few earlier cases lipiodol examinations of the bronchi were done here; it was impossible however to get any lipiodol into the emphysematous cavity. I would further refer to the pressure experiments carried out which show that communication exists though this is undoubtedly very small. Bronchi are very poorly filled and reduced to about half the size of those on the other side. Stenotization of the bronchi can thus be observed, a feature noticed before in connection with the production of a bullous emphysema. For my own part I rather favour the original diseased process located further out into the bronchial branches — unrevealed on the radiogram — on account of the character of the process being some damage to the parenchyma. It is also a strange fact that the communication with the bronchi had become so much reduced, seeing that the parenchyma was so largely destroyed. In the localised forms of bullous emphysema we get as a rule narrowing of the afferent bronchi, as for instance in JÆDERHOLM's case, and I should not doubt that such narrowing is of some etiological importance. Also in diffuse bullous emphysemata, such as the present case and as in HAAHTI's and ENSIGN's cases, the same phenomenon has been found. Nevertheless the close mechanism in these cases still seems to me obscure and will probably only be solved by patho-anatomical examinations. In the present case there were also signs of an early bullous emphysema at the base of the other lung.

Still another point would seem worth being discussed. From what has been said already it would appear that the condition presents the picture of some damage to the parenchyma without the slightest sign of infection. And yet in this as also in other cases there is a history of a prolonged chronic bronchitis with sputa, though of varying quantities, for several years. I am unable to offer any explanation as to the rôle played by the chronic bronchitis.

In several cases previously published exploration by needle of the emphysema — on account of the case having been diagnosed as spontaneous pneumothorax — has resulted in death within a few hours. In LEWIS' case it was probably an instance of bilateral pneumothorax with suffocation. In the present case numerous pneumothorax punctures as well as thoracoscopy were carried out without any serious effects. The latter was performed with a big trocar. To my mind I think that the larger the emphysematous cavity, the less is the risk of such an operation and the less chance is there to cause damage to the parenchyma itself and to bring about air emboli, haemorrhage or other complications.

In the present case thoracoscopy was carried out on a wrong diagnosis. Even if thereby the diagnosis was made clear I think nevertheless one should warn against such an interference, particularly in cases of smaller emphysematous cavities of that nature. In the case of a larger cavity it would seem that conditions coincide more with an ordinary pneumothorax.

SUMMARY

The case is of diagnostic interest since it had been regarded for a long time as a spontaneous pneumothorax and the correct diagnosis was only made through thoracoscopy. This form of examination also raised points of interest in regard to the nature of the disease.

ZUSAMMENFASSUNG

Der Fall ist von diagnostischem Interesse, weil er lange Zeit für einen spontanen Pneumothorax gehalten worden war, und die richtige Diagnose nur durch Thorakoskopie erhalten wurde. Diese Untersuchungsform hat auch interessante Punkte in Bezug auf die Natur dieses Leidens ins Licht gerückt.

RÉSUMÉ

Le cas est d'intérêt diagnostique car il avait longtemps été pris pour un pneumothorax spontané, et le diagnostic correct n'a pu être effectué que par la thoracoscopie. Ce mode d'examen présente aussi de l'intérêt eu égard à la nature de la maladie.

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FROM THE ROENTGEN DEPARTMENT, MARIA HOSPITAL, STOCKHOLM.
CHIEF: ÅKE ÅKERLUND, M. D.

ROENTGEN-ANATOMICAL STUDIES OF THE LABYRINTH[1]

by

Knut Wolke

(Tabulæ XCI—XCIII)

The labyrinth of the temporal bone is a useful point of orientation for the otologist as well as the radiologist. So is the former, for example, in exploring the mastoid process, well guided by the bulging of the different semicircular canals into the cell system, particularly should this be widespread and reach far into the petrous bone. The latter in his description of changes observed can refer to the semicircular canals, the vestibule and the cochlea which always appear more or less distinctly on the radiogram. Yet roentgen-anatomical details are not brought out on the radiograms of living subjects or of anatomical specimens, wherefore contrast studies of the labyrinth would be desirable for gaining a wider knowledge of it. A detailed and clear view would then be obtained of the position of the semicircular canals in relation to other cavitations of the temporal bone and to one another as also of the projections of the vestibule and cochlea in reference to, for instance, the external auditory canal and the tympanum. Such knowledge might perhaps prove useful in the examination of labyrinthine fistulae and in judging the position of lesions in relation to the semicircular canals etc.

As far as the author has been able to find out such contrast examinations of the roentgen-anatomy of the labyrinth have only been undertaken by STENVERS in the projection mentioned by him. MAYER, LYSHOLM and RUNSTRÖM describe the labyrinth in projections advanced by them, to which excellent diagrams and explanations have been prepared. But none of them has carried out any contrast examinations of the labyrinth.

As the LYSHOLM-RUNSTRÖM projections are those found most useful in this country the author has carried out a few contrast studies in

[1] Submitted for publication April 24th, 1935.

some of their projections. For the purpose a number of temporal bones were sawn through by a fret-saw, after which the semicircular canals, the vestibule and the basal convolution of the cochlea were filled up with red lead. In none of the specimens did the author succeed in filling up the apical convolutions. After sticking together the specimens they were stereoscopically radiographed in positions corresponding to the

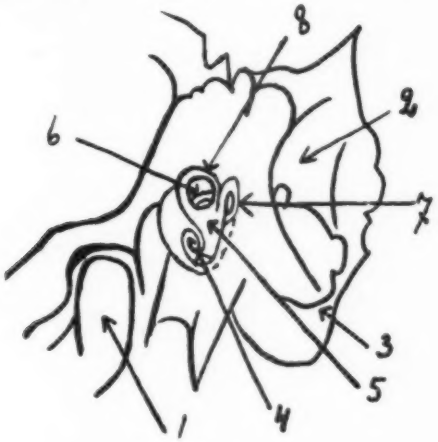

Fig. 3.

1. Mandibular joint.
2. Sinus sigmoideum.
3. Incisura digastrica.
4. Cochlea.
5. Vestibulum.
6. Lateral semicircular canal.
7. Posterior semicircular canal.
8. Anterior semicircular canal.

three LYSHOLM-RUNSTRÖM projections most in use (p_I, p_{II} and p_{IV}). A fourth projection (p_{III}) was not included since it is practically identical with STENVER's.

In the following projections employed will be named after LYSHOLM and are denoted by the abbreviations suggested by RUNSTRÖM and referred to above.

»*Lateral projection or* p_I»: The skull in side-lying position with a point corresponding to the middle of the external meatus in the centre of the film. The central ray is centred with a cranial angle of 15°.

»*Axial orthoprojection in lateral position or* p_{II}»: Position as in p_I. A point about 2 cm. caudally of the external meatus is placed in the centre of the film. The central ray is directed with a cranial angle of 35° against this point.

»*Axial projection or* p_{IV}»: The patient in supine position in such a way that, if possible, a plane through the eye-ear line comes to run pa-

rallel with the plane of the film. The central ray bisects the line between the external auditory meati at a right angle with the eye-ear plane.

The pictures obtained in each projection are stereoscopic and by viewing the reproductions (fig. 1, 4 and 7) by divergent visual axes a good stereoscopic effect is obtained. All the pictures are of the right temporal bone and to each projection there is a diagram (fig. 3, 6 and 9) and

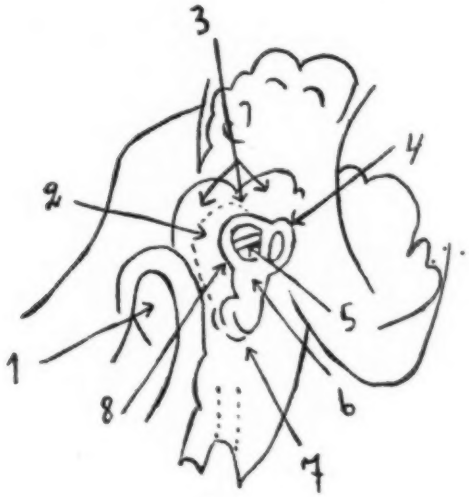

Fig. 6.

1. Mandibular joint.
2. Tympanic cavity.
3. Atticus, aditus ad antrum and antrum.
4. Posterior semicircular canal.
5. Lateral semicircular canal.
6. Vestibulum.
7. Cochlea.
8. Anterior semicircular canal.

a photograph of a labyrinthine mould in the same projection (fig. 2, 5 and 8).

Projection p_I (fig. 1, 2 and 3). — The bone is seen obliquely from above and from within at an angle of 15° with a plane through the eye-ear line. In the ovoidal clear area brought about by the external auditory canal and the tympanum the vestibule is projected in the place where a round clear area has generally been observed. This was considered caused by the internal porus until LYSHOLM and RUNSTRÖM pointed out that both the internal porus and the vestibule were responsible for it; the same has now been shown by the author's investigations. On the distal aspect of and extending from the vestibule the basal convolution of the cochlea (as already mentioned the apical convolutions could not be filled up) is ob-

served. The anterior and posterior semicircular canals with their crus commune are facing the observer — the former almost annular in shape and the latter placed more edge-wise. The lateral semicircular canal is mostly hidden from view by the vestibule and the crus commune. Only its anterior lateral part can just be seen within the curve of the anterior canal.

Projection p_{II} (fig. 4, 5 and 6). — The bone is seen obliquely from above and from within at an angle of 35° with a plane through the eye-ear line. The contrast-medium-filled labyrinth is projected in and just behind the ovoidal rarefied area caused by the external auditory

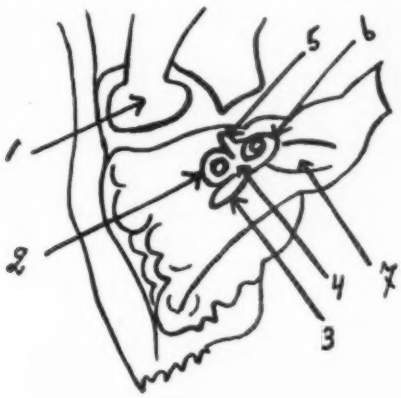

Fig. 9.

1. Mandibular joint.
2. Lateral semicircular canal.
3. Posterior semicircular canal.
4. Vestibulum.
5. Anterior semicircular canal.
6. Cochlea.
7. Internal auditory canal.

canal and atticus. The vestibule and the basal convolution of the cochlea are projected within the posterior parts of the projection of the external auditory canal. Where the basal convolution springs from the posterior part of the vestibule there is an irregular shadow occasioned by some quantity of the opaque medium expelled through the round window. Facing the observer are the upper and posterior semicircular canals with the crus commune. The anterior canal is projected within the projected area of the atticus and, partly hidden from view by the crus commune, the lateral semicircular canal appears as a closed ring.

Projection p_{IV} (fig. 7, 8 and 9). — The bone is seen straight from below. The lateral semicircular canal appears as a closed ring arising from the vestibule, and behind it is seen the posterior canal placed edgewise facing the observer. The posterior and upper part of the anterior canal is

obscured by the vestibule wherefore its anterior part only can be seen in front of the latter. Medially is seen the basal convolution of the cochlea and internally to this the internal porus acusticus is seen projected as an ovoidal rarefied area.

SUMMARY

With the view to studying the labyrinth the author filled it with red lead in a number of specimens of the temporal bone, after which he took radiograms of them; in so doing he used three of the projections advanced by LYSHOLM and RUNSTRÖM for examining the temporal bone. The radiograms obtained are analysed and the roentgen anatomy is described.

ZUSAMMENFASSUNG

Um das Labyrinth zu studieren, füllte Verf. es in einer Anzahl von Schläfenbeinen mit Menning und machte dann Röntgenaufnahmen des Knochens in drei von den Projektionen, die LYSHOLM und RUNSTRÖM zur Untersuchung des Schläfenbeins angegeben haben. Verf. analysiert die erhaltenen Bilder und beschreibt die Röntgenanatomie.

RÉSUMÉ

Pour étudier le labyrinthe l'auteur a rempli celui-ci de minium dans un certain nombre d'os temporaux et ensuite il a radiographié ceux-ci dans trois des projections indiquées par LYSHOLM et RUNSTRÖM pour l'examen de l'os temporal. Les images obtenues sont analysées et l'anatomie radiographique est décrite.

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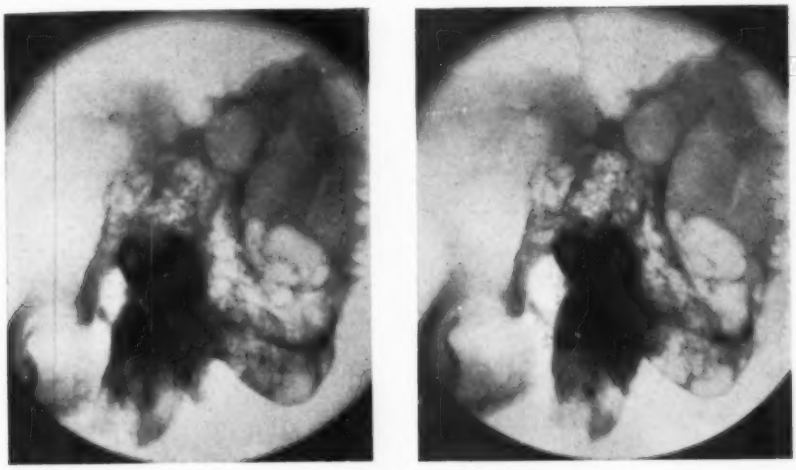

Fig. 1.

Fig. 2.

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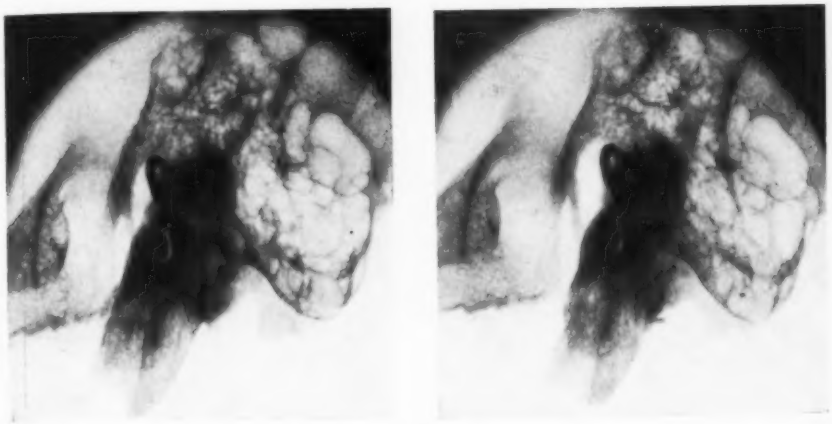

Fig. 4.

Fig. 5.

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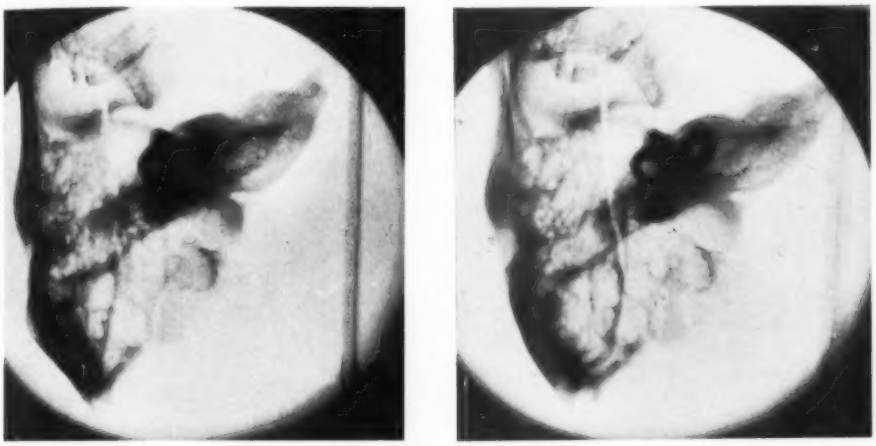

Fig. 7.

Fig. 8.

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SERVICE DE RADIOLOGIE DU OERESUNDSHOSPITALET, COPENHAGUE
(MÉDECIN-CHEF DE SERVICE: D[R] AAGE O. WOLFF)

CONTRIBUTION A LA TOPOGRAPHIE DES GANGLIONS INTRATHORACIQUES, SURTOUT A L'ÉGARD DE LA TUBERCULOSE DES GANGLIONS BRONCHIQUES[1]

par

Aage O. Wolff

(Tabulæ XCIV—XCVI)

Si nous examinons l'image radiographique du thorax dans la tuberculose pulmonaire chez les enfants — un examen sur lequel, à part la tuberculine et la démonstration du bacille, s'appuie, pour ainsi dire le diagnostic entier — nous ne manquerons pas d'observer la grande différence qui existe entre cette image pendant les deux premières années de la vie, où, à cause du manque de résistance de la part de l'enfant, le mal prend vite un caractère étendu, sous la forme soit de pneumonies lobaires spécifiques, soit d'une tumeur universelle des ganglions intrathoraciques, et l'image présentée par la même affection dans le groupe nombreux de cas entre les âges de 2 et 14, où l'on arrive très vite au type que depuis le temps ancien l'on appelle la tuberculose des ganglions bronchiques, et qui s'exprime sous la forme d'une affection ganglionnaire circonscrite, déterminée par l'allergie.

Comme c'est généralement le cas des infections aérogènes, les signes du début sont pourtant le petit foyer exsudatif pulmonaire, bientôt résorbé, et l'infection ganglionnaire régionale, qui surgit presque en même temps, mais qui, à cause de son étendue bien plus grande, devient le trait dominant dans l'image radiographique; tandis que le foyer pulmonaire se laisse rarement repérer, d'un côté parce qu'il est fugitif, d'un autre côté parce qu'il peut être caché dans des parties du poumon invisibles dans les radiographies ordinaires de cet organe. Comme c'est avant tout aux ganglions intrathoraciques que nous allons consacrer

[1] Communication faite à la Société Danoise de Radiologie et à la Société Danoise des Médecins Spécialistes de la Tuberculose, à Copenhague, le 11 avril 1935.

cette étude, il n'y a pas lieu d'entrer dans le détail des autres formes sous lesquelles s'exprime la tuberculose, telles que la tuberculose miliaire, la pleurésie exsudative, assez rare, du reste, chez des sujets de cet âge, etc.

Pour bien comprendre la disposition des ganglions intrathoraciques, nous pouvons nous servir du tableau dressé par ENGEL,[1] qui a étudié les rapports, entre eux, des différents groupes ganglionnaires, au moyen de coupes en série des organes thoraciques fixés en bloc avec le formol, et qu'il a reconstruits ensuite. Ses recherches ont eu pour résultat de modifier le tableau, pendant longtemps universellement accepté, de SUKIFANNIKOW; ENGEL ayant démontré, entre autres choses, que les ganglions sont situés dans les angles formés par les vaisseaux, et non pas, comme l'on avait supposé jusqu'alors, le long de l'arbre bronchique. Comme le groupement que nous avons trouvé nous-mêmes, correspond précisément au tableau d'ENGEL, nous reproduisons ce dernier ci-dessous:

Tableau d'après ENGEL.

à 1. — Il va de soi que les deux ganglions de la bifurcation sont invisibles dans la radiographie prise de face, tandis qu'ils sont facilement visibles dans la radiographie prise en oblique, où la bifurcation est précisément le point de repère le meilleur. Le ganglion du côté droit est le plus grand, et peut atteindre des dimensions considérables.

à 2. — En l'état pathologique, le ganglion trachéo-bronchique droit est juste visible au bord de l'ombre médiastinale; agrandi il fait saillir cette dernière en courbe plate. A l'état normal de la largeur d'un noyeau de datte, il peut, dans des cas exceptionnels, atteindre les dimensions de 25 × 50 millimètres. En commun avec les ganglions de la bifurcation, il est facilement atteint du moment que l'infection a passé les premières stations hilaires.

[1] ENGEL et VON PIRQUET: Handbuch der Kindertuberkulose.

à 3—6. — Ces groupes de ganglions hilaires constituent ce qu'on appelle généralement les ganglions bronchiques et broncho-pulmonaires. Ils dépassent, en partie, l'ombre médiane. Selon ENGEL, les ganglions hilaires postérieurs joueraient un rôle important pour le développement de la complication si fréquente de pleurésie interlobaire; ce qui s'explique par le fait de leur situation juste au-dessous de la plèvre interlobaire. On considère généralement ces ganglions comme les plus aisément lisibles dans la radiographie de face, mais ceci peut être le cas seulement des plus périphériques, et surtout de ceux du côté droit; et encore cela ne peut-il être affirmé qu'avec certaines réserves.

La densité de la tumeur parenchymateuse — c'est à dire le commencement de tuméfaction inflammatoire du ganglion — n'est pas suffisante pour rendre visible ce dernier. Ce n'est que la dégénérescence caséeuse, plus tard, avec la formation de tissu conjonctif et la calcification qui lui succèdent, dont l'ombre nous impressionne; et cela s'applique d'une façon égale à tous les ganglions. Les stages fraîches on ne les voit pas; et c'est là une chose qu'il importe de remarquer, afin de pouvoir éviter d'interpréter faussement les phénomènes d'ombre absolument normaux dans la région des hiles; nous pensons ici aux ombres circulaires, ovales et canaliculaires portées par les vaisseaux, que, dans les bonnes radiographies, on distingue aisément les unes des autres, et des clartés marquant les bronches remplies d'air. Quand on parle de ganglions hilaires, dans l'image radiographique, il s'agit donc *soit* d'amas de ganglions tuméfiés tellement volumineux que, par la densité de leur ensemble, ils nous impressionnent comme des tumeurs (forme tumorale), *soit* des signes indirects d'affection ganglionnaire consistant en la réaction périfocale avec œdème, hyperémie, infiltration, atélectasie et la réaction pleurale dont nous venons de parler.

C'est à cet agrandissement et à cette opacification des ombres hilaires qu'ENGEL donne le nom *d'hilitis;* une désignation qui doit être reservée pour le processus périganglionnaire, tandis que plusieurs autres peuvent simuler un tel processus. Ainsi faut-il tenir compte de la condensation périfocale autour de foyers pulmonaux n'appartenant à la région hilaire, mais qui sont projetés avec cette dernière, d'autant plus facilement que le foyer primitif pulmonal est souvent situé dans la partie postérieure, médiane, du poumon. Enfin, il est souvent impossible de discriminer une pneumonie circonscrite dans ces régions d'une »hilitis», sauf au moyen d'un examen radiographique en oblique. Pour ces raisons, le mot »périhilaires» employé sans préciser la localisation, nous paraît impropre, surtout si l'on voudra en étendre l'application jusqu'à comprendre l'image presque-lobaire de l'épi-tuberculose. A notre avis, le mot »périfocales» est une désignation à la fois plus propre et plus neutre pour les condensations diffuses, inflammatoires, dans les régions hilaires

et autour de celles-ci. On sait qu'un image semblable peut être produit par n'importe quelle affection ganglionnaire autre que la tuberculose, ainsi que par la stase dans des affections cardiaques.

à 6—8. — Reste à considérer les deux dernières groupes ganglionnaires. Tandis que l'écoulement de la lymphe s'effectue, dans le poumon droit entier et dans le lobe inférieur du poumon gauche, par la voie des groupes ganglionnaires déjà nommées, le lobe supérieur du poumon gauche a ceci de particulier que ses ganglions ne sont pas situés aussi près de la trachée et des bronches principales, mais au voisinage des grands vaisseaux. Le ganglion du conduit de Botalli se trouve juste en dedans du bord gauche du médiastin, celui de l'arc aortique au-dessus de la plèvre péricardiaque (ENGEL). Ces deux groupes ont à peu près la même chance de devenir visibles dans la radiographie ordinaire de face que l'a le ganglion trachéo-bronchique droit; il n'est pas rare du tout de le voir isolément calcifié dans des cas où il existe soit des traces d'une affection du lobe supérieur du poumon gauche, soit des données anamnestiques concernant une telle affection.

Nous avons maintenant passé en revue les ganglions intrathoraciques, et nous avons vu qu'ils ne paraissent que faiblement dans les radiographies ordinaires du poumon. Est-ce qu'on aura plus de chance de les rendre visibles au moyen d'une radiographie en oblique? Pour autant qu'on puisse voir de la littérature, les essais qu'on a faits pour répondre à cette question, en ce qui concerne les ganglions intrathoraciques et le diagnostic des affections hilaires, n'ont pas bien réussi.

Il va de soi que les manuels les plus récents font mention de la radiographie en oblique, mais les renseignements qu'ils fournissent sur l'application de ce mode d'examen aux ganglions thoraciques sont peu détaillés. LIEBMANN, de Zurich, recommande la radioscopie et la radiographie en 1^{e} et 2^{e} positions obliques; mais, à ce qui paraît, il emploie la projection dorso-ventrale. LESTOQUOY et LEHMANN (1929) sont les auteurs qui se sont le plus occupés de la même question qui nous intéresse ici; ils arrivent à la conclusion que la radiographie prise en oblique donne des ombres massives, à contours flous, inutilisables pour le diagnostic ganglionnaire en dehors des cas où il s'agit de véritables tumeurs du médiastin. En revanche, ils trouvent que la radiographie prise *de profil* donne des contours nets et laisse clair la zone située à la hauteur des 5^{e} et 6^{e} vertèbres dorsales, au niveau de laquelle on doit rechercher l'affection ganglionnaire. Cette opinion est partagée par ARMAND-DELILLE, LESTOQUOY et VIBERT (1929). ED. SCHULZ (1931) a pratiqué la radiographie en 1re position oblique, dans le but de découvrir les ganglions de la bifurcation; il pense qu'il a réussi de les observer dans des sujets adultes, — sans foyer pulmonal. ANÉ et MENVILLE ont pratiqué l'injection du péricarde par du thorotrast pour mettre en évi-

dence les ganglions et les vaisseaux lymphatiques. HERRNHEISER (1933) a compté les ombres ganglionnaires calcifiées dans des radiographies thoraciques ordinaires, et en a dressé un tableau, mais sans utiliser la radiographie en oblique.

Si, comme nous le croyons, nous avons obtenu des résultats un peu meilleurs que n'ont obtenu les auteurs qui nous ont précédé dans ces recherches, c'est probablement en premier lieu parce que nous avons utilisé l'orientation *ventro-dorsale* des rayons. Par ce procédé, le cœur, qui dans la radiographie oblique est l'obstacle principal à la mise en évidence de détails intrathoraciques, se trouve tellement éloigné du film qu'au lieu d'être un obstacle il devient, par sa densité uniforme, un fond servant à faire ressortir le dessin des hiles. Il va de soi que les rayons doivent posséder une puissance de pénétration assez considérable pour qu'on puisse obtenir, à travers l'ombre cardiaque, l'image des bronches et des ramifications vasculaires.

En 1930 et 1931, nous pratiquâmes une série de recherches de la radiographie en profil du thorax, surtout sur des enfants; mais nous arrivions bientôt à la conclusion qu'il n'y avait aucun avantage à obtenir dans le film la somme des deux ombres hilaires. Il était impossible de se faire une idée juste d'un »trop» ou »trop peu», mais surtout de décider laquelle des deux ombres était la plus dense. Il fallait absolument essayer de séparer les ombres hilaires, et cette séparation est possible seulement dans une certaine projection oblique. Après maints essais nous réussissions à trouver cette projection, ainsi que l'orientation la plus favorable, et depuis 1932 nous pratiquons méthodiquement, dans l'examen du thorax chez les enfants, la technique que nous allons décrire dans un moment, de radiographie en position oblique, tantôt droite, tantôt gauche. Nous trouvions que l'orientation ventro-dorsale était la plus favorable, et nous nous sommes arrêtés à une rotation de 30° du frontal; de sorte qu'en position oblique *postérieure* droite la face dorsale du thorax reste appliquée contre la cassette porte-film. Si l'on regarde alors le négatif du côté opposé au sujet (et au tube de roentgen) — le »côté pellicule» — l'on verra la bronche droite dirigée *en avant* par rapport aux organes et aux parties squelettiques, et la bronche gauche dirigée en arrière; et dans la radiographie prise en position oblique postérieure gauche on a sous les yeux l'image exactement contraire. Quand on s'est habitué à cette projection, on s'étonne du peu d'obstacle que présentent à la vue et les os et l'ombre cardiaque.

L'analyse plus détaillée d'une telle radiographie prise en oblique droite, avec le sujet en position assise, les bras levés au-dessus de la tête, et appuyé soit à l'appareil, soit à un long bâton, ou bien, supporté par un assistant (il va de soi qu'il s'agit de maintenir la pose aussi constante que possible), montre *l'omoplate* comme une plaque tout à fait trans-

parente dans le premier plan de l'image, surmontée par l'articulation scapulo-humérale, l'humérus et la clavicule; le bord médian est à peine visible; on ne voit que le bord latéral, l'angle de l'omoplate et la ligne divisée de l'épine. Le *sternum* est projeté de sorte qu'il laisse libre le champ qui nous intéresse particulièrement. La *colonne vertébrale* forme un arc dans le champ pulmonaire gauche, et *l'omoplate gauche* se voit en profil net au dehors du thorax, dans le fond de l'image.

L'ombre cardiaque, de laquelle on pourrait croire qu'elle serait le pire obstacle à notre essai, peut presque être considérée comme un avantage. Elle sert comme un fond homogène, transparent, à la région hilaire; à la condition, évidemment, que les rayons possèdent une certaine puissance de pénétration, telle qu'on peut l'obtenir, par exemple, au moyen d'un transformateur avec une soupape (modèle Järnh, Stockholm), à 60 kilovolts, 60 milliampères, distance focale 1 mètre, temps de pose 0.05 seconde. Le rôle joué par les côtes est aussi insignifiante dans la radiographie prise en oblique que dans celles prises de face, sauf dans les cas très rares où elles forment une surface unie, sans intervalles. Les deux moitiés du diaphragme sont bien en vue; on remarque surtout la courbe, concave en arrière, de la plèvre, depuis le péricarde jusqu'au diaphragme droit. Finalement, on doit tenir compte des ombres mammaires et de la bulle d'air de l'estomac.

Tournant des alentours à la région des hiles, nous avons, comme notre point de repère le plus important, la clarté trachéale avec les deux bronches principales, qui se dessinent toujours nettement avec des parois bien définies, et la bifurcation. L'on voit la bronche droite dans la partie antérieure du thorax, et l'on peut souvent distinguer les ramifications les plus proches, autour desquelles se groupent les ganglions. La bronche gauche se dirige en arrière, et se perd dans l'ombre de la colonne vertébrale.

Nous avons donc réussi à séparer les deux bronches principales, et il s'agit maintenant de savoir jusqu'à quel point il est à supposer que, dans cette position oblique, le poumon opposé — ici le poumon gauche — envahit le champ pulmonaire droit. Pour nous orienter à cet égard, nous avons premièrement les deux courbes du diaphragme, deuxièmement la position des ombres calcifiées de la région hilaire gauche. Pour essayer d'éclairer la question, et reconnaissant que des essays avec injection de poumons soit préparés, soit *en situ*, ne donnent aucun résultat qui aie de valeur, nous avons enfin pratiqué aussi la radiographie en oblique, tantôt droite, tantôt gauche, de cas d'exsudation pleurétique unilatérale. Comme résultat de ces divers examens, nous avons trouvé que, vu en projection oblique postérieure droite, avec une rotation de 30° — le sujet étant placé dans la position déjà décrite — le poumon droit s'étale jusqu'à l'ombre de la colonne dorsale, sans la dépasser; et

que le bord extrême, antérieur, du poumon gauche, dans la même position, arrive juste à la bifurcation; ce qui laisse entre les deux ombres hilaires une distance suffisante pour qu'on puisse les étudier séparément, — préférablement chacune de son côté, parce qu'ainsi on aura pour fond l'ombre cardiaque homogène, dont nous avons déjà parlé.

Pour montrer la disposition des diverses groupes ganglionnaires dans les projections en oblique droite et gauche, nous avons choisi des cas de ganglions calcifiés; mais il va de soi qu'on ne devra pas voir dans ces démonstrations autre chose qu'un essai de topographie, en position oblique, tant de ganglions que d'»ombres hilaires». Elles ne disent rien concernant l'apparition des ganglions dans des cas frais, sur laquelle nous nous sommes déjà exprimés plus haut.

Les radiographie ci-jointes démontrent d'une façon absolument claire qu'il est possible 1) d'observer séparément chacune des ombres hilaires, dans toute son étendue, et non plus masquées par les organes thoraciques; 2) de se faire une idée de la largeur du médiastin en avant de la trachée, dépendant de l'existance possible d'une tumeur ganglionnaire; 3) de déterminer le siège exact de processus infiltratoires, tuberculeux ou pneumonaux, par rapport à la colonne vertébrale ou dans les parties basales du poumon; et finalement, 4) d'obtenir une vue d'ensemble de la disposition des différentes groupes ganglionnaires: le ganglion trachéo-bronchial à droite, dans l'angle formé par la trachée et la bronche droite; les deux ganglions situés dans la bifurcation nettement visible; les ganglions hilaires, antérieurs et postérieurs, des deux côtés, qui apparaissent de sorte que les ganglions individuels se trouvent mieux espacés que dans la radiographie de face; et finalement, les deux groupes du lobe supérieur du poumon gauche, où la relation intime qui existe entre les processus pulmonaire et ganglionnaire, régionale, peut être le mieux observée. Dans la radiographie prise en oblique postérieure gauche on trouvera ces ganglions projetés bien en avant de la trachée, à cause de leur situation près des grands vaisseaux.

Nous avons obtenu la confirmation du rôle joué par les vaisseaux pulmonaires dans la radiographie normale; et nous voyons comment, du même calibre et à la même distance du hile, ils donnent, en projection oblique, des ombres arrondies, précises; mais ces recherches ont aussi démontré qu'une ombre hilaire, même nettement circonscrite, n'est pas nécessairement pathologique, pourvu qu'elle est d'une densité uniforme.

Enfin, ces radiographies prises en oblique postérieure droite et gauche nous montrent que dans la tuberculose chez les enfants les processus frais, rélativement circonscrits, ne donnent aucune ombre directe sur le film, ni dans la projection frontale, ni dans les projections obliques que nous venons de décrire.

RÉSUMÉ

L'auteur décrit brièvement l'image radiographique de la tuberculose des ganglions pulmonaires (adénopathie trachéo-bronchique tuberculeuse) chez les enfants, et rapporte sur une méthode de radiographie du thorax, en oblique postérieure, dont il montre qu'elle est d'une valeur spécifique dans l'analyse des régions hilaires par le fait qu'elle permet de scruter, séparément, chacune de ces régions, ainsi que les ganglions intrathoraciques, dans une étendue bien plus grande que cela n'est possible par la radiographie ordinaire de face, en projection dorso-ventrale. Il appelle l'attention, surtout, au peu d'importance qu'ont les ombres ganglionnaires pour le diagnostic, de bonne heure, du processus actif.

SUMMARY

The author briefly describes the roentgenological image of tuberculosis of the pulmonary lymph nodes (tuberculous tracheobronchial adenopathy), and calls attention to a

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Tabula XCIV

Fig. 1. Radiographie en oblique postérieure droite de poumon normal. La trachée, les bronches droite et gauche, ainsi que le hile droit, se dessinent sur l'ombre cardiaque homogène.

Fig. 2. Tous les ganglions sont calcifiés, et visibles seulement en partie.

Fig. 3. Même que le précédent, en oblique postérieure droite. On voit le ganglion trachéo-bronchique droit dans l'angle formé par la trachée et la bronche droite, le ganglion de la bifurcation, et les ganglions hilaires bien séparés les uns des autres.

Fig. 4. Même que les deux précédents, en oblique postérieure gauche. Ici les ganglions du côté droit sont projetés sur la bronche droite et sur la bifurcation. Le hile gauche se dessine sur l'ombre cardiaque.

Tabula XCV

Fig. 5. Ganglion de la bifurcation en oblique postérieure droite.

Fig. 6. Ganglion trachéo-bronchique droit en oblique postérieure droite. On note la manière typique dont il reste libre dans cette projection.

Fig. 7. Ganglions hilaires, peu visibles.

Fig. 8. Les mêmes, en oblique postérieure droite; on note les ombres séparées, bien distinctes.

Tabula XCVI

Fig. 9. Ganglion de l'arc aortique, dans le bord de l'ombre vasculaire.

Fig. 10. Le même, en oblique postérieure gauche, projeté en avant de l'ombre vasculaire. Foyer pulmonaire. Densification du hile.

Fig. 11. Intumescence du ganglion trachéo-bronchique et infiltration du poumon droit.

Fig. 12. Même thorax en oblique postérieure droite, montrant densification dans la partie antérieure du champ pulmonaire et largeur accrue du médiastin en avant de la trachée, — mais sans ombres ganglionnaires, même 1 mois après, quand l'infiltration du poumon avait disparu.

Fig. 1.

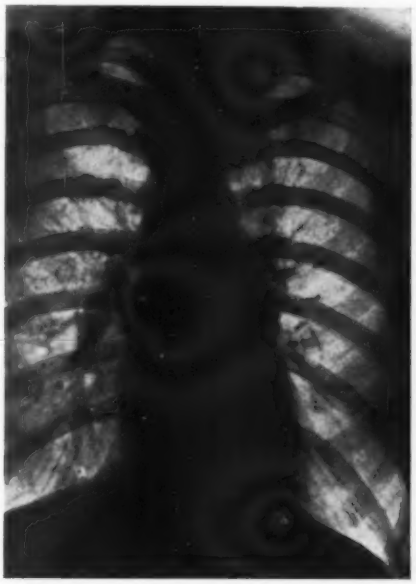

Fig. 2.

Fig. 3.

Fig. 4.

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Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

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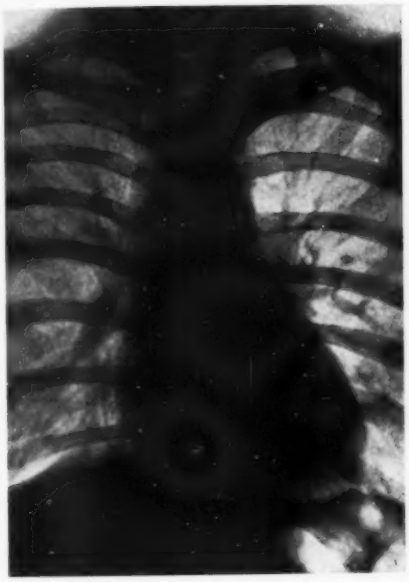

Fig. 9.

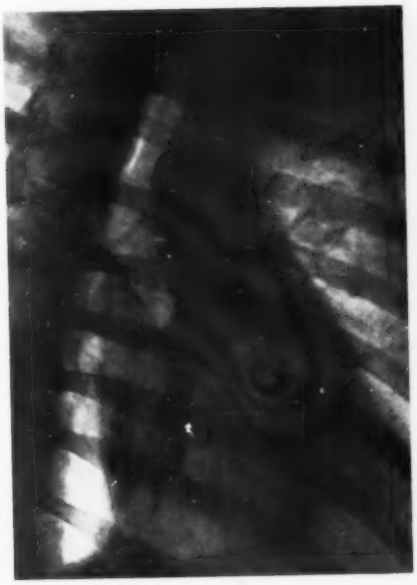

Fig. 10.

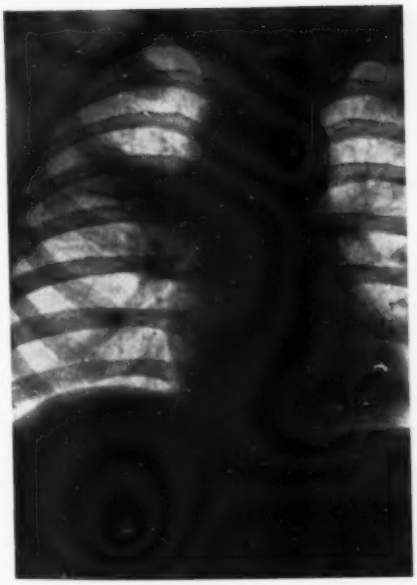

Fig. 11.

Fig. 12.

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method for radiography of the thorax, in oblique posterior projection, which he shows to be particularly valuable as a means of analysing the hilar regions, because it makes it possible to scrutinise each of those regions separately, and with a range very much larger than what is possible with the usual radiography in straight dorsoventral projection. He calls especial attention to the fact that the lymph node shadows are of very little importance as regards an early diagnosis of the active process.

ZUSAMMENFASSUNG

Verf. beschreibt kurz das Röntgenbild bei Tuberkulose der Lungenlymphdrüsen (Bronchialdrüsentuberkulose) der Kinder und berichtet über eine Methode, bei welcher der Thorax schräg von hinten aufgenommen wird. Er zeigt, dass diese Methode von spezifischem Wert für die Analyse der Hilusregionen ist, dadurch, dass sie gestattet, jede von diesen Regionen separat gründlich zu untersuchen, und auch die intrathorakalen Lymphdrüsen in weit grösserer Ausdehnung darzustellen als es bei gewöhnlicher Radiographie en face mittels dorso-ventraler Projektion möglich ist. Verf. verweist ferner besonders auf die geringe Wichtigkeit, die die Lymphdrüsenschatten für die Frühdiagnose eines aktiven Prozesses haben.

AUS DER RÖNTGENABTEILUNG DES UNIVERSITÄTSKRANKENHAUSES IN UPSALA
(CHEF: PROFESSOR H. LAURELL)

ÜBER ZWEI SELTENE ANOMALIEN(?) IM CARPUS[1]

(»Verschmelzung» von Os lunatum und Os triquetrum sowie von Os multangulum minus und Os capitatum)

von

Lars Lönnerblad

(Tabulæ XCVII—XCVIII

Verf. hatte Gelegenheit, in einem Material von etwa 2100 Handgelenken folgende drei Fälle zu beobachten, in denen das Lunatum und das Triquetrum der einen Handwurzel zusammen einen Knochen bildeten.

Fall 1. B. L., 17 Jahre, Landwirtstochter, die immer gesund und bisher keinem schwereren Trauma ausgesetzt gewesen war. Die Eltern sind nicht miteinander verwandt. In der Familie sind keine Missbildungen bekannt. Pat. kam am 28. 10. 1934 wegen Verdachts einer Fraktur in der rechten Handgelenkgegend auf die hiesige Röntgenabteilung. Am vorhergehenden Tage war sie gefallen, wobei sie die rechte Hand vorgestreckt und sofort starke Schmerzen im Handgelenk gefühlt hatte. Bei der Aufnahme im Krankenhaus bestand mässige Empfindlichkeit um das rechte Handgelenk, am stärksten in der Gegend des Processus styloideus ulnae, und etwas beschränkte Beweglichkeit des Handgelenks. Das linke Handgelenk zeigte völlig normale Beweglichkeit. Kraft in beiden Händen gut.

Bei *Röntgen*untersuchung wurde folgendes festgestellt (Fig. 1: beide Handgelenke in Radialabduktion; Fig. 2: beide Handgelenke in Ulnarabduktion):

Rechte Hand: Ein kleines Fragment vom Processus styloideus ulnae abgesprengt. Keine nennenswerte Verlagerung. Sowohl im Triquetrum am Gelenk gegen das Lunatum wie im Lunatum am Gelenk gegen das Triquetrum bestand eine zystenartige Verdünnung etwa von der Grösse einer russischen Erbse. Sonst keine Skelettveränderungen sichtbar. Die Knorpeldistanz zwischen Lunatum und Triquetrum nicht merklich vermindert. Die Gelenkflächen von Radius und Ulna zeigten im Radiocarpalgelenk keinen nennenswerten Niveauunterschied (weniger als 1 mm). *Linke* Hand: Im Carpus fanden sich bloss 7 Knochen, da der Platz des Lunatum und des Triquetrum von einem Knochenblock eingenommen war, der nach Form und Grösse durch Verschmelzung dieser beiden Knochen oder unterbliebene Teilung ihrer gemeinsamen Anlage entstanden zu sein schien. Die distale Fläche dieses Blocks wies in der Gegend der vermuteten Grenze zwischen Lunatum und Triquetrum eine 1 mm tiefe Furche auf. Diese Grenze schien im

[1] Bei der Redaktion am 19. VIII. 1935 eingegangen.

übrigen durch eine streifenförmige, undeutliche Verdichtung in der Spongiosa angedeutet zu sein, die sich vom Grunde der erwähnten Furche bis zu der proximal gerichteten Kortikalisschicht erstreckte. Auf beiden Seiten der Verdichtung zeigte die Spongiosa innerhalb eines erbsengrossen Gebiets eine gewisse Verdünnung, deutlich also an der entsprechenden Stelle wie die oben beschriebenen Verdünnungen im Lunatum und Triquetrum der rechten Hand. Im übrigen bot die linke Handwurzel dasselbe Bild wie die rechte.

Am Fussskelett der Patientin war keine Anomalie zu bemerken.

Nach 3-wöchiger Fixation des rechten Handgelenks in Gipsschiene und nachfolgender 2-wöchiger Bewegungsbehandlung war die Verletzte völlig beschwerdenfrei.

Auf Aufforderung fanden sich 16 Angehörige der Patientin ein (Grosswater mütterlicherseits, Mutter, Vater, ein Bruder, drei Brüder der Mutter, ein Vetter und zwei Basen mütterlicherseits sowie eine Schwester des Vaters und deren fünf Kinder, von denen drei unter 12 Jahre alt waren). Keine dieser Personen zeigte eine Anomalie im Hand- oder Fussskelett. Ein 3-jähriger Vetter wies im rechten Fuss die für Morbus Köhler I typische Verdichtung und Kompression des Knochenkerns im Naviculare auf, jedoch ohne irgendwelche subjektive Beschwerden.

Fall 2. E. P., die jetzt 23-jährige Ehefrau eines Telegraphenamtsarbeiters. Pat. wurde 1927 auf der hiesigen Röntgenabteilung wegen klinischen Verdachts von Morbus Kienböck untersucht. Sie hatte damals seit einem Jahr ziemlich oft Schmerzen im linken Handgelenk gehabt und Empfindlichkeit über der Gegend des Mondbeins gespürt. Kein Trauma bekannt. Früher keine Beschwerden seitens der Handgelenke. Die Eltern sind nicht miteinander verwandt. In der Familie sind keine Missbildungen bekannt.

Bei *Röntgen*untersuchung am 17. 3. 1927 zeigte das linke Handgelenk keine Veränderungen, die rechte Handwurzelgegend dagegen eine Anomalie wie in dem oben beschriebenen Fall 1. (Die Bilder wurden nicht aufgehoben.)

Auf meinen Wunsch kam Pat. am 6. 12. 1934 zur Nachuntersuchung. Sie war seit der letzten Untersuchung im wesentlichen beschwerdenfrei gewesen. Die Beweglichkeit beider Handgelenke war völlig normal und auf beiden Seiten gleich. Kraft einwandfrei.

Bei *Röntgen*untersuchung wurde folgendes beobachtet:

Linkes Handgelenk röntgenologisch normal.

Das *rechte* Handgelenk zeigte, nach der Beschreibung der vorigen Röntgenuntersuchung zu urteilen, ein unverändertes Bild. Wie aus Fig. 3 ersichtlich ist, war auf der distalen Fläche des »Blockes» in diesem Fall im Gegensatz zu Fall 1 keine deutliche Furche wahrzunehmen, ebensowenig eine merkliche Strukturveränderung in der Gegend der vermuteten Grenze zwischen Lunatum und Triquetrum.

Das Fussskelett der Patientin wies keine Anomalie auf.

Fall 3. H. P., 35 Jahre, Landwirtsehefrau. Bei *Röntgen*untersuchung i. J. 1927 wurde als Nebenbefund in der einen Handwurzel ein Bild wie in Fall 1 beobachtet. Pat. starb einige Jahre danach, so dass man sie nicht nachuntersuchen und nähere Auskünfte einziehen konnte. Auf dem erhaltenen Bild (Fig. 4) sieht man wie in Fall 1 eine reichlich 1 mm tiefe Furche auf der distalen Fläche des »Blockes», dagegen keinen verdichteten Streifen in der Spongiosastruktur wie in Fall 1.

Ausserdem hat Verf. in dem erwähnten Material einen Fall beobachtet, in dem auf der rechten Seite und wahrscheinlich auch auf der linken eine *ossöse Verbindung zwischen Multangulum minus und Capitatum* bestand.

S. G., 35 Jahre, Arzt. Seit etwa 10 Jahren bei angestrengtem Arbeiten mit der rechten Hand mässige Schmerzen und unbedeutende Empfindlichkeit in der Handwurzel in der Gegend des Multangulum minus. Seit ungefähr derselben Zeit hat er hier am Handrücken eine pfenniggrosse, rundliche, platte, feste Resistenz (Ganglion?) bemerkt. Eine ähnliche Erhebung — aber weniger ausgesprochen — hat er lange auf dem linken Handrücken gehabt. Niemals Schmerzen im linken Handgelenk.

Bei Untersuchung am 19. 1. 1935 bestand normale Beweglichkeit der Handgelenke, keine Empfindlichkeit über den erwähnten Prominenzen. Kraft der Hände sehr gut. Die Sehne des M. palmaris longus konnte auf der linken Seite nicht gefühlt werden.

Bei *Röntgen*untersuchung ergab sich folgendes:

Rechte Hand. Ausgebreitete Synostose zwischen Multangulum minus und Capitatum (Fig. 5). Besonders deutlich zeichnete sich die Knochenbrücke zwischen den beiden Knochen in ihrem proximalen Teil ab. (Die Untersuchung wurde durch Stereobilder ergänzt). Handwurzelskelett sonst o.B.

Linke Hand. Wahrscheinlich Synostose zwischen Multangulum minus und Capitatum, jedoch weniger ausgeprägt als auf der rechten Seite.

Das Fussskelett zeigte keine Anomalien.

Verf. hatte nicht Gelegenheit, die Angehörigen des Patienten zu untersuchen.

»Verschmelzungen» von zwei oder mehr Handwurzelknochen finden sich oft gleichzeitig mit anderen Varietäten oder Missbildungen im Skelett der oberen Extremität. KÜMMEL, JOACHIMSTHAL, NIGST u. a. haben derartige Fälle veröffentlicht, in denen die »Verschmelzung» von Handwurzelknochen von sekundären Interesse gegenüber schweren Missbildungen des Extremitätsskeletts im übrigen war. Ein Fall von rechtsseitigem kongenitalem Radiusdefekt (Fig. 6) bei einer 28-jährigen Frau ist an der hiesigen Röntgenabteilung zur Untersuchung gekommen.

Die Handgelenke (Fig. 6 u. 7) zeigten folgende anormale Verhältnisse: *Rechte* Hand (Fig. 6): Nur Seitenbild aufgenommen. Nach diesem lässt sich nicht sicher entscheiden, ob in der proximalen Reihe zwei Knochen vorhanden sind oder möglicherweise nur einer. Die Handwurzel ist volar-proximal luxiert. Ulna verkürzt und stark bogenförmig gekrümmt. Das dünne Metacarpale I ist mit einem Knochenblock verschmolzen, der offenbar den miteinander vereinigten Knochen Multangulum majus und minus entspricht. (Ausserdem fehlen Phalangen am Zeigefinger.) Im *linken* Handgelenk (Fig. 7) ist das Naviculare nur durch einige bis linsengrosse Knocheninseln angedeutet. Das Capitatum ist am Radius eingelenkt. Das Lunatum ist stark ulnarwärts verlagert. Multangulum majus und minus sind möglicherweise miteinander »verschmolzen».

GRASHEY hat einen Fall von »doppelseitiger Synostose des Lunatum, Triquetrum, Hamatum und eines Teiles(?) des Capitatum» bei einem 11-jährigen Mädchen beschrieben, das auch Verwachsungen u. a. zwischen Talus, Calcaneus, Naviculare und Cuboideum hatte.

Bei angeborener *4-fingriger* Hand sind meist »Verschmelzungen» von Handwurzelknochen vorgekommen, so z. B. in STRECKERS Fall, wo Lunatum und Triquetum zusammen einen Knochen bildeten, ebenso Capitatum und Hamatum. In WRETES Fall dagegen wies die Handwurzelgegend keine Anomalie auf.

Tabelle über isolierte, einseitige oder doppelseitige »Verschmelzungen» von Lunatum und Triquetrum.

Autor:	Geschlecht:	Alter:	Seite:
Soemmering	?	? J.	*r.* und *l.*
Sandifort	?	? »	einseitig?
Perrin de la Touche	?	? »	*l.*
Phoebus	m.	30 »	*r.* und *l.*
Holl	m.	26 »	*r.* und *l.*
Anderson	?	? »	?
Paterson	m.	20 »	*r.*
Smith, E.	m.	35 »	*r.* und *l.*
Derry	w.	? »	*r.* und *l.*
Derry	m.	? »	*l.*, *r.* nicht untersucht
Corson	m.	»erwachsen»	*r.* und *l.*
Smith, A.	w.	»erwachsen»	*r.* und *l.*
Grashey	w.	25 J.	*r.* und *l.*
Grashey	?	? »	einseitig
Epstein	w.	50 »	*r.*
Kniepkamp	w.	22 »	*r.*
Kniepkamp	?	21 »	*l.*
Bogart	?	? »	?
Bogart	?	? »	?
Devois	m.	? »	*r.* und *l.*
Dupas u. Badelon	m.	20 »	*r.* und *l.*
Dupas u. Badelon	m.	20 »	*r.* und *l.*
Esau	m.	15 »	*r.* und *l.*
Sorokin	w.	42 »	*r.* und *l.*
Kremser	m.	14 »	*r.* und *l.*
Lönnerblad	w.	17 »	*l.*
Lönnerblad	w.	23 »	*r.*
Lönnerblad	w.	35 »	einseitig?

Wagner, Jourdan und Humphry erwähnen je einen Fall, wahrscheinlich handelt es sich um Soemmerings Fall. Dwight soll verschiedene Fälle von Anomalie im Carpus beobachtet haben, doch war mir seine Arbeit nicht zugänglich. Pfitzner erwähnt 6 Fälle von partieller »Verschmelzung» des Lunatum mit dem Triquetrum.

Mestern hat i. J. 1934 Fälle von hauptsächlich doppelseitiger »Blockbildung» in Handwurzel und Fusswurzel sowie Aplasie von Interphalangealgelenken veröffentlicht. Diese Anomalien waren ausgesprochen *hereditär*. Als Beispiel verschiedener Kombinationen führe ich Mesterns Familie O. an. Vater: Die Hände zeigten Synostose von Multangulum, minus, Capitatum und Hamatum, die Füsse Synostose von Naviculare und Talus, Metatarsale II und Cuneiforme II. Seitensymmetrie. — Sohn, 12 Jahre. Hände: Synostose von Lunatum und Triquetrum, Verschmelzungsbrücke zwischen Multangulum minus und Capitatum, Synostose von Multangulum majus und Metacarpale I. Füsse o.B. — Tochter, 7 Jahre. Hände: Synostose von Hamatum und Triquetrum beiderseits,

Synostose von Capitatum und Hamatum rechts. Füsse: »Synostose von Os cuboideum und Cuneiforme II und III, sowie von Naviculare und Talus und Kuboid mit Kalcaneus». — Sohn, 5 Jahre. Hände: Synostose von Hamatum und Triquetrum. (Die Kerne von Multangulum majus, M. minus und Naviculare sind auf dem Röntgenbild nicht sichtbar.) Füsse: »Synostose von Navikulare und Talus, sowie Cuneiforme II und III und Kuboid».

Im Gegensatz zu diesen Fällen ist »Verschmelzung» zweier Handwurzelknochen als *isolierte* Anomalie des Extremitätsskeletts ziemlich selten. Verf. hat in der Literatur nur etwa 50 solche Fälle gefunden, bei denen es sich in reichlich 20 um »Synostosen» zwischen Lunatum und Triquetum handelt.

Diese letztere Kategorie ist die gewöhnlichste. Die beigefügte Tabelle bietet eine Übersicht der zu dieser Klasse gehörenden Fälle mit Angabe der Autoren, des Geschlechts und Alters der untersuchten Fälle sowie darüber, ob die Anomalie einseitig oder doppelseitig war.

Die Beweglichkeit des anormalen Handgelenks ist nur von Corson, Kniepkamp, Devois, Sorokin und Kremser geprüft worden und hat sich in sämtlichen Fällen als normal erwiesen. Das Fussskelett wurde von Soemmering, Phoebus, S. A. Smith, Sorokin und Kremser untersucht, doch wurde hier keine Anomalie von ihnen festgestellt. Nur Kniepkamp und Sorokin haben die Untersuchung auf Angehörige ausgedehnt. Der erstere hat das Handskelett auch beim Vater, bei der Mutter und einer Schwester des Patienten untersucht, der letztere Hand- und Fussskelett eines Bruders, zweier Schwestern und einer Tochter seiner Patientin. Hierbei waren keine Anomalien festzustellen. In 9 Fällen ist die Anomalie bei Negern beobachtet worden: Soemmering, Paterson, E. Smith, Derry (2 Fälle), Corson, Dupas u. Badelon (2 Fälle), S. A. Smith (Australnegerin).

In einem grossen Teil der Fälle bestand eine mehr oder minder flache Furche auf der distalen Fläche des »Blockes»; dagegen wird in keinem Fall mitgeteilt, dass die proximal gerichtete Gelenkfläche eine Furche aufgewiesen habe.

»*Verschmelzung*» *von Multangulum minus* und *Capitatum* wird von Anderson, S. A. Smith, Dwight, Cave, Wette, Linow sowie Bogart erwähnt.

Verf. hat keinen Fall von isolierter »Synostose» zwischen Lunatum und Capitatum oder zwischen Lunatum und Hamatum in der Literatur gefunden, wohl aber eine Anzahl anderer Formen von »Synostose» im Handgelenk, so »Verschmelzung» von Naviculare und Lunatum (Dwight, Bogart), von Naviculare und Multangulum majus (Kautz, Turner), von Naviculare und Multangulum minus (Bogart, der jedoch in diesem

Fall den Autor nicht nennt), von Naviculare und Capitatum (WEDDING, RUCKENSTEINER), von Triquetrum und Pisiforme (WEDDING, BOGART), von Multangulum majus und minus (RUCKENSTEINER, BOGART), von Capitatum und Hamatum (PFITZNER, DWIGHT, LINOW, BOGART).

Es erscheint Verf. bisweilen schwierig, bei isolierten, unilateralen Blockbildungen aus zwei Handwurzelknochen zu entscheiden, ob dieselben kongenital, d. h. als Anomalien im eigentlichen Sinn zu betrachten sind, oder ob sie ihre Entstehung einem pathologischen Prozess verdanken. Verschiedenes spricht dafür, dass es sich in den allermeisten Fällen um echte Anomalien handelt. Wenigstens dürfte es sehr ungewöhnlich sein, dass z. B. ein entzündlicher Prozess Synostose bloss zwischen zwei Handwurzelknochen hervorruft, da die Gelenke zwischen den Carpalknochen miteinander kommunizieren und praktisch niemals isoliert angegriffen werden. Meines Wissens hat niemand einen derartigen Fall veröffentlicht. Dagegen hat HAGLUND einen Fall publiziert, wo ein destruktiver Prozess (Tuberkulose?) im Talonaviculargelenk bei einem Kinde ausgeheilt war und man später eine vollständige Coalitio talo-navicularis fand. (H. sagt nicht, wie es sich mit dem hinteren Teil der Articulatio talo-calcaneo-navicularis verhielt.)

Es ist eine bekannte Tatsache, dass zwei zu einem gewissen Zeitpunkt getrennte Knochenkerne später oft verschmelzen; das Naviculare carpi z. B. bildet sich ja aus zwei verschmelzenden Kernen. Gleichartige Verschmelzungen können sowohl bei Syndesmosen wie bei Synchondrosen stattfinden, ja sogar bei Diarthrosen, vorausgesetzt, dass die letztgenannten lange genug immobilisiert gehalten werden. Während des postembryonalen Lebens dürfte eine solche Möglichkeit selten bestehen. Die Voraussetzung für eine spät eintretende Verschmelzung dürfte für Multangulum minus und Capitatum relativ günstig sein, da diese Knochen bei Bewegungen der Hand bedeutend geringere Verschiebungen gegeneinander erfahren als die Knochen in der proximalen Reihe des Carpus.

Verf. ist in der Literatur keinem Versuch begegnet, zu erklären, weshalb Lunatum und Triquetrum relativ häufig zu verschmelzen scheinen, und kann auch selbst keine Erklärung hierfür geben. Bisher haben sich keine Anhaltspunkte für die Annahme ergeben, dass diese Anomalie erblich ist. In Fall 1 des Verfassers wurden 16 Angehörige untersucht, von denen kein einziger eine Anomalie aufwies.

Bei mehreren Forschern findet man die Angabe, dass »Verschmelzung« von Lunatum und Triquetrum bei Negern besonders gewöhnlich sei. Es ist nicht ausgeschlossen, dass es sich so verhält; doch ist diese Frage meines Wissens bisher nicht näher untersucht worden. Wie bemerkt, handelt es sich in 9 der von mir in der Literatur angetroffenen Fälle um Neger. Die betreffenden Autoren teilen indes nicht mit, wie gross das

untersuchte Material war, ausser in DERRYS 2 Fällen. Von 40 im Anatomiesaal in Kairo untersuchten Körpern waren 6 Sudanneger, und von diesen hatten 2 die fragliche Anomalie. Bei Röntgenuntersuchung der Neger der Garnison (wie viele?) wurde indes kein einziger Fall festgestellt. — BOGART macht bei seinem Material von 1452 untersuchten Handgelenken keine Angaben über die Rasse. — CORSON sagt, er habe viele Handgelenke von Farbigen untersucht, aber nur einen Fall angetroffen.

Ob eines der beiden Geschlechter oder eine Körperseite mehr für die genannten Anomalien disponiert ist, lässt sich nach diesem kleinen Material nicht entscheiden.

Bei vielen Säugetiergruppen findet sich normaliter Vereinigung gewisser Carpalknochen. So bilden z. B. bei den Carnivora das Naviculare und das Lunatum einen Knochen, das Scapho-Lunatum, und bei den Pecora sind Multangulum minus und Capitatum »verschmolzen». Dagegen kommt, soviel mir bekannt, ein Lunato-Triquetrum nur als Anomalie vor.

Normalerweise sind das Multangulum minus und das Capitatum durch Bänder straff miteinander verbunden, weshalb es selbstverständlich erscheint, dass eine Verschmelzung dieser beiden Knochen keine merkliche Bewegungsbeschränkung herbeiführen kann. Dagegen erfolgt bei Radial- und Ulnarabduktion eine gewisse Verschiebung des Triquetrum im Verhältnis zum Lunatum. Diese Verschiebung kann bei Synostose zwischen den genannten Knochen nicht stattfinden, aber die Beweglichkeit des Handgelenks hat nichtsdestoweniger in den von Verf. untersuchten Fällen keine Beschränkung aufgewiesen, ebensowenig in den übrigen veröffentlichten Fällen, in denen sie geprüft wurde. KNIEPKAMP sagt allerdings, dass der Patient in seinem Fall bei extremen Bewegungen des Handgelenks Schmerzen gehabt habe; doch dürfte es zweifelhaft sein, ob diese durch die »Verschmelzung» bedingt waren.

(Da bisweilen bei *Fussinsuffizienz* mehr oder minder ausgebreitete »Verschmelzungen» von Fusswurzelknochen beobachtet worden sind, hat man — vielleicht mit einem gewissen Recht — einen Zusammenhang zwischen den Beschwerden des Patienten und der Anomalie angenommen; siehe u. a. BORGGREVE).

Eine eingehende Prüfung des Verhaltens der Carpalknochen bei verschiedenen Bewegungen der anomalen Handgelenke sollte nach den Richtlinien erfolgen, die FORSSELL in seiner Arbeit über die Mechanik des Handgelenks aufgestellt hat. Ich gehe hier nicht auf dieses Thema ein. Zur Vermeidung von Fehlerquellen infolge der Projektion können vielleicht Fernphotographieren oder Orthodiagraphieren von gewissem Wert sein.

Die Genese der zystenartigen Verdünnungen im Lunatum und Triquetrum in den Fällen 1 und 3 ist unsicher. HULTÉN hat darauf hingewiesen, dass man oft traumatische Zysten unter anderem im Lunatum

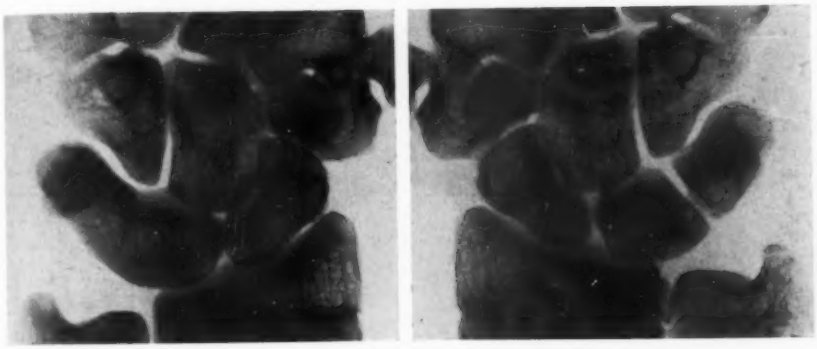

Fig. 1.

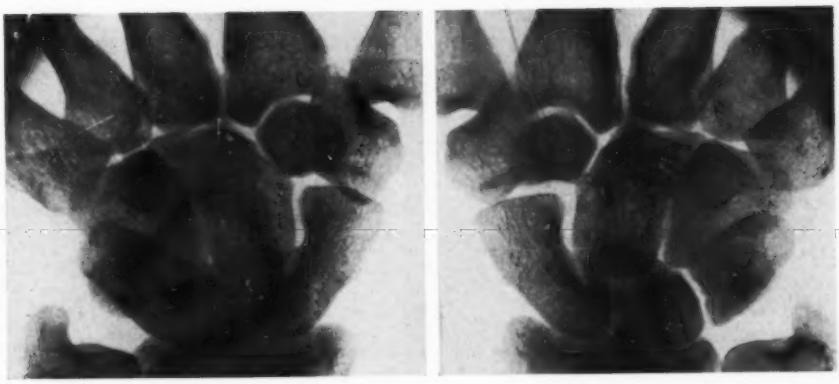

Fig. 2.

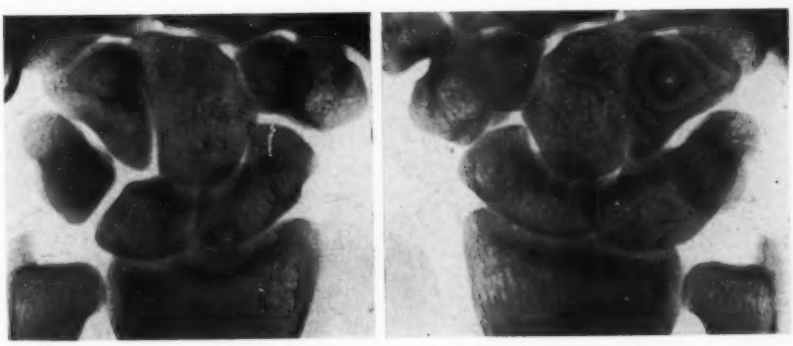

Fig. 3.

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Fig. 4.

Fig. 7.

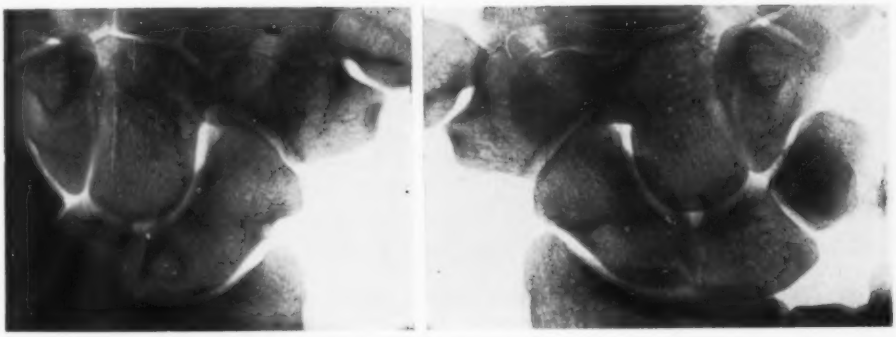

Fig. 5.

Fig. 6.

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findet, wenn die Ulna weiter distalwärts reicht als der Radius, was ja in meinen Fällen nicht zutraf.

Ein Fall von Fraktur oder Luxation eines Lunatum-Triquetrum-Blockes ist meines Wissens nicht untersucht worden, ebensowenig ein Kienböck-artiges Bild.

Ein nennenswerter Strukturumbau in den verschmolzenen Knochen, wie er bei Synostosen z. B. in der Fusswurzel vorkommt, ist nicht beobachtet worden; die Belastung des Handgelenks ist ja auch verhältnismässig gering.

ZUSAMMENFASSUNG

Verf. berichtet über 3 Fälle von »Verschmelzung» des Lunatum und des Triquetrum als isolierter Anomalie des Handskeletts sowie über einen Fall von »Verschmelzung» des Multangulum minus mit dem Capitatum und gibt eine Übersicht über ähnliche, früher veröffentiichte Fälle.

SUMMARY

The author describes three cases of »fusion» of the semilunar (os lunatum) and cuneiform (os triquetrum) as the single anomaly in the hand-skeleton, and one case of »fusion» of trapezoid (os multangulum minus) and os magnum (os capitatum) and gives at the same time a survey of similar cases previously published.

RÉSUMÉ

L'auteur décrit 3 cas de »fusion» de l'os semi-lunaire et de l'os pyramidal comme seule anomalie du squelette de la main ainsi qu'un cas de »fusion» de l'os trapézoïde et du grand os; ensuite l'auteur donne une revue des cas semblables antérieurement publiés.

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AUS DER RÖNTGENABTEILUNG DES UNIVERSITÄTSKRANKENHAUSES IN UPSALA
(CHEF: PROF. H. LAURELL)

DER NACHWEIS MINIMALER, BEI GEWÖHNLICHER LUNGENUNTERSUCHUNG OFT UNSICHTBARER PLEURAEXSUDATE. ZUGLEICH EIN BEITRAG ZUR DIFFERENTIALDIAGNOSE BEI »LAMELLÄRER PLEURITIS» UND BEI BASALER VERSCHLEIERUNG[1]

von

Hugo Laurell

(Tabulæ XCIX—C)

Kleine und grosse Pleuraexsudate können bekanntlich in der Regel leicht durch Röntgen nachgewiesen werden, mögen sie frei oder abgekapselt sein. Das freie Exsudat sammelt sich in aufrechter Stellung vor allem basal, und ist es klein, so füllt es zunächst den Sinus phrenicocostalis aus und erstreckt sich von da kephalwärts längs der lateralen Thoraxwand als ein allmählich schmäler werdender oder gleichschmaler Randstreifen von einem oder einigen Millimetern Dicke (JACCOUDS épanchement lamelliforme, FLEISCHNERS lamelläre Pleuritis, SCHÖNFELDS pleuritische Lungenrandlinie). Diese typischen Pleuritisbilder haben auch viele andere Forscher beobachtet, ohne ihnen besondere Namen zu geben. Oft findet man bei Untersuchung in aufrechter Stellung trotz klinisch leicht nachweisbarer Pleuritis bloss einen etwa 1 mm schmalen derartigen Randstreifen, welcher mit einer minimalen Ausfüllung in Sinus phrenicocostalis verschmilzt. Untersucht man dagegen den Patienten in Seitenlage mit der kranken Seite nach unten, so sieht man in diesen Fällen oft, dass es sich um ziemlich grosse Pleuraexsudate handelt, die allerdings bei gewöhnlicher Technik in der Hauptsache unsichtbar sind (HJELM, Verf.). Dieses wechselnde Aussehen beruht darauf, dass die Flüssigkeit, die bei aufrechter Stellung hinter (und bisweilen auch

[1] Vortrag im Schwed. Verein für med. Radiologie am 8. XII. 1934; bei der Red. am 29. VI. 1935 eingegangen.

vor der Zwerchfellkuppel) verborgen liegt, sowie die, welche in einer dünnen Schicht über die ganze Lungenoberfläche und interlobär ausgebreitet ist, sich bei dieser Seitenlage vor allem längs der lateralen Thoraxwand ansammeln. Der Randstreifen nimmt deshalb bedeutend an Dicke zu, oft so hochgradig, dass die Bezeichnung Randstreifen oder Randlinie nicht mehr passt. Zu der vermehrten Dicke des Randstreifens trägt auch der Umstand bei, dass die Oberfläche der nach unten liegenden Lunge viel kleiner ist als dieselbe Lungenfläche bei aufrechter Stellung, und zwar infolge der Hochlage des Zwerchfells auf der nach unten liegenden Seite und der Senkung des Mediastinums nach derselben Seite. Die in der Flanke angesammelte Flüssigkeit hat bei Seitenlage eine im wesentlichen horizontale obere Grenze und wächst also an Mächtigkeit gegen den Sinus phrenicocostalis hin, der bei dieser Körperstellung infolge der Form des Thorax den tiefsten Punkt des Flüssigkeitsbassins bildet. Als Beispiele für die grosse Variation der Mächtigkeit der Flüssigkeitsschicht beim Übergang aus sitzender Stellung in Seitenlage sei angeführt, dass die Dicke, gemessen oberhalb der Scapulaspitze, in einem Fall von 1 auf 12 mm und in einem anderen von 2 auf 25 mm zunahm. Dieses Verfahren, die Verschiebbarkeit und Grösse eines Pleuraexsudats nachzuweisen, ist mit Erfolg von mehreren Autoren angewandt worden [Hjelm u. Verf., Gomez u. Heidenreich (zit. Rigler), Polgár, Rigler].

Wichtig ist es, sich daran zu erinnern, dass *ein Pleuraerguss vorhanden sein kann, obgleich Mantelschatten und Ausfüllung des Sinus phrenicocostalis ganz fehlen*, und dass dabei die Lunge völlig normal erscheinen und das Zwerchfell freie oder fast freie Verschiebbarkeit besitzen kann. Um in solchen Fällen die Flüssigkeit nachzuweisen, haben Hjelm und Verf. die oben beschriebene Methode angewandt. In einem Vortrag am 17. IX. 1929 im Upsalaer Ärzteverein über die Röntgendiagnose akuter Bauchfälle wurde als ein wichtiges und gewöhnliches Zeichen einer Entzündung im oberen Teil der Bauchhöhle ein kleines, bei gewöhnlicher Technik oft unsichtbares Pleuraexsudat erwähnt und gleichzeitig die Methode zum Nachweis desselben mit Röntgen angegeben. Der Vortrag wurde in Svenska läkartidningen 1930 sowie in Acta chirurg. scandinavica im gleichen Jahre veröffentlicht. Aus diesen Aufsätzen sei folgendes angeführt: »Bei tiefem Einatmen verteilt sich ein sehr kleines Exsudat bisweilen im Sitzen über so grosse Teile der Lungenoberfläche (und interlobär), dass es auf dem Röntgenbild völlig unsichtbar wird, während es deutlich als ein etwa bleistiftbreiter Mantelstreifen in der Flanke hervortritt, wenn man das Bild während des Ausatmens und in Seitenlage mit der verdächtigen Seite nach unten aufnimmt, wobei natürlich mit horizontaler Strahlenrichtung photographiert wird. In anderen Fällen erscheint das kleine, bewegliche Exsudat in Rücken-

lage als eine sichelförmige, homogene, die Lungenspitze umgebende Kappe, während es bei aufrechter Stellung ganz unsichtbar ist, wenn die Lungenplatte, wie es gewöhnlich geschieht, während des Einatmens aufgenommen wird.» Im Schwedischen Verein für medizinische Radiologie hat HJELM am 9. XI. 1929 über dasselbe Thema gesprochen, und später (1931) ist die Verschiebbarkeit der Pleuraexsudate ausführlicher von HJELM und Verf. in der Zeitschrift Upsala Läkareförenings Förhandlingar erörtert worden. Ein gleichartiges Verfahren zum Nachweis minimaler Pleuraexsudate hat RIGLER später i. J. 1931 beschrieben und ausserdem den grossen Wert einer Untersuchung in Seitenlage mit der kranken Seite nach unten in den Fällen hervorgehoben, wo die Diagnose Pleuritis zweifelhaft ist oder wenn es gilt, zu entscheiden, ob ein flüssiges oder ein organisiertes Exsudat vorliegt.

RIGLER *hat ebensowenig wie* HJELM *und Verf. die später von* KNUTSSON, HERRNHEISER, KUBAT und NEUGEBAUER *angegebenen Fehlerquellen bei der Diagnose dünner Mantelexsudate berücksichtigt*, nämlich die normalen, subpleuralen Gewebe, welche Begleitschatten geben können, und zwar wahrscheinlich deshalb, weil sich bei dieser Lageänderung das Bild bei freiem Exsudat oft so stark verändert, dass sich die Diagnose »freies Pleuraexsudat» von selbst ergibt. Jedoch muss man, namentlich im Hinblick auf KNUTSSONS Arbeit über subpleurale Muskelschichten (mm. intercost. int. und mm. subcost.), die ähnliche Bilder wie bei lamellärer Pleuritis geben können, daran denken, bei Seitenlage mit genau derselben Strahlenrichtung wie in aufrechter Stellung zu untersuchen, so dass bei den verschiedenen Aufnahmen nicht verschiedene Teile der Thoraxwand randbildend werden. Vor allem muss man verhindern, dass sich der Patient in Seitenlage etwas nach hinten dreht, denn bei horizontaler Strahlenrichtung werden dann, wie KNUTSSON anatomisch gezeigt hat, die genannten subpleuralen Muskeln oft konturbildend. Dieselbe Fehlerquelle muss man natürlich auch in den Fällen beachten, wo man ein dünnes Mantelexsudat bei aufrechter Stellung wahrnimmt.

Auch die von NEUGEBAUER unter anatomischem Gesichtspunkt studierten physiologischen Fettansammlungen unter der Pleura parietalis (siehe später), die hinten stärker entwickelt sind als in der Flanke, können denkbarerweise zu gleichen diagnostischen Irrtümern Anlass geben.

In der ersten Mitteilung (siehe oben) wurde gesagt, dass Untersuchung von minimalem freiem Pleuraexsudat durch Photographieren in Seitenlage mit der verdächtigen Seite nach unten beim *Ausatmen* stattfinden solle, weil der Exsudatmantel dann am dicksten ist. Man kann jedoch auch in Mittelstellung oder beim Einatmen photographieren, wobei das Bild kontrastreicher, die Exsudatschicht aber relativ dünner

wird. Bei fetten Personen kann das letztere Verfahren vorzuziehen sein, um ein deutlicheres Bild zu erhalten. RIGLER hat diese letztere Methode benutzt.

Das Photographieren in Seitenlage ist seit langem auch von anderen Autoren ausprobiert worden, aber zu anderen Zwecken, z. B. um die nach oben liegende Lunge mit mehr Luft zu füllen und so dort befindliche Einzelheiten besser sichtbar zu machen, ferner um das Zwerchfell bei normalen und pathologischen Zuständen zu studieren oder um einen kleinen Pneumothorax besser sehen zu können oder flüssigkeitsgefüllte Kavitäten in Lunge und Pleura zu untersuchen usw. BROWN hat kürzlich mit gutem Resultat den diagnostischen Wert dieser für gewisse Zwecke anerkannt wertvollen Methode geprüft, den Patienten in Seitenlage mit der kranken Seite nach oben zu untersuchen. Unter anderem beschreibt er einen Fall von abgekapseltem Empyem sowie einen von Seropneumothorax, wo Bilder in dieser Körperstellung bessere Aufschlüsse gaben als Bilder in aufrechter Stellung. Seltsamerweise stellt er diese Methode in Gegensatz zu dem oben angegebenen Verfahren, das freie Exsudat in Seitenlage mit der kranken Seite nach unten zu studieren, indem er sagt, dass er mit seiner Methode bessere Ergebnisse erhalte. Er schreibt nämlich: »In this position the heart shifts toward the healthy side, thus exposing the unhealthy side to more accurate inspection.» Dieser Scbluss trifft nicht für alle Fälle zu und kann nicht unwidersprochen bleiben; denn benutzt man diese Methode mit der kranken Seite nach oben, um z. B. kleine, bei gewöhnlicher Untersuchung unsichtbare Pleuraergüsse nachzuweisen, so bekommt man ein unrichtiges Ergebnis, wie nachstehendes Beispiel zeigt.

In einem Fall von akuter Paranephritis sah man bei Lungenuntersuchung im Sitzen kein Pleuraexsudat noch andere Pleuritiszeichen, abgesehen von einem geringen Nachschleppen auf der kranken Seite (Fig. 1, Tabula I). In Seitenlage mit der kranken Seite nach unten trat dagegen eine deutliche Mantelpleuritis hervor (Fig. 2), die aber bei umgekehrter Seitenlage mit der kranken Seite nach oben wieder unsichtbar wurde (Fig. 3), im geraden Gegensatz zu dem, was man nach BROWNS Darstellung erwarten sollte.

In Fällen von Pleuritis mit etwas grösserem freiem Exsudat, wo die vom Exsudat umspülten basalen Lungenteile mehr oder weniger atelektatisch sind, bekommt man unbestreitbar kontrastreichere Bilder mit der kranken Seite nach oben. Aber in diesen Fällen steht die Diagnose schon nach einer gewöhnlichen Lungenuntersuchung in aufrechter Stellung fest. Warum das Pleuraexsudat in diesen Fällen zum grossen Teil in der Flanke, vor allem basal, zurückbleibt, haben HJELM und Verf. in anderem Zusammenhang erörtert. Dies beruht oft nicht auf Abkapselung, sondern in erster Linie auf der basalen Lungenatelektase, die eine Folge der Pleuritis ist. Erst wenn die nach oben liegende atelekta-

tische Lungenbasis lufthaltig wird, kann sie den Platz des Exsudats in der Flanke einnehmen, wobei dieses nach dem Mediastinum hin sinkt. Hieraus erklärt sich, dass kleinere Pleuraexsudate, die bei dieser Seitenlage (mit der kranken Seite nach oben) den phrenicokostalen Winkel einnehmen, bisweilen zum Verschwinden gebracht werden können, wenn der Patient wiederholt tief atmet, wobei die basale Atelektase verschwindet — eine Beobachtung, die auch POLGÁR gemacht hat, ohne jedoch eine Erklärung zu versuchen.

Bei grossen abgekapselten Pleuraexsudaten, wie in einem der von BROWN angeführten Beispiele, ist es selbstverständlich besser, mit der kranken Seite nach oben zu untersuchen, ebenso auch bei vielen anderen Zuständen, wo die kranke Lunge aus dem einen oder anderen Grunde stark verschleiert ist. Auch an der hiesigen Röntgenabteilung wird seit langem diese Methode benutzt, um unter anderem basale Lungenatelektase und unsichere Lungeninfiltrate zu studieren. *In gewissen Fällen, wo es sich darum handelte, die Art einer basalen Verschleierung bei der Fragestellung »Atelektase, Pleuritis oder Infiltrat?» zu ermitteln, wurde in beiden Seitenlagen photographiert,* wobei der Patient zuerst auf die kranke Seite gelegt wurde, um festzustellen, ob ein freies Pleuraexsudat zu der basalen Verschleierung beitrug, und dann auf die gesunde, um die nach oben liegenden verschleierten Lungenteile lufthaltiger zu bekommen und so mehr Einzelheiten in der Lungenbasis zu erhalten. Der Wert dieses Verfahrens, das in zahlreichen Fällen zur Anwendung kam, soll durch nachstehendes Beispiel beleuchtet werden:

Differentialdiagnose in einem Fall von basaler einseitiger Verschleierung (Film nr: 17927/1929). Letztere war auf eine einige Zentimeter breite Zone oberhalb des Zwerchfells beschränkt und klang nach oben ab (Fig. 4, Tabula II). Das Zwerchfell schleppte deutlich auf der kranken Seite nach, doch fehlte bei aufrechter Stellung ein typischer basaler Pleuritisschatten, der sich in einen Mantelschatten fortsetzt. Die Grenze des Zwerchfells gegen die Lunge war infolge Fehlens von Luft in den basalen Lungenteilen oder infolge von Interposition in der Pleura — welches von beidem war anfangs nicht festzustellen — völlig verschwunden. Als der Patient auf die kranke Seite gelegt wurde, erhielt man keinen für freie Pleuritis sprechenden Mantelschatten. Als man Pat. dann mit der kranken Seite nach oben legte und ihn einige tiefe Atemzüge tun liess, hellte sich die verschleierte Lungenbasis völlig auf, so dass die Kontur des Zwerchfells scharf hervortrat. *Als Pat. nun im Sitzen photographiert wurde, blieb die Lungenbasis luftig und behielt normales Aussehen, und das Zwerchfell zeigte normale Beweglichkeit* (Fig. 5). Dieser Versuch ergab also, dass die Verschleierung und das Nachschleppen vor allem auf einer Atelektase beruhten, mochte dieselbe nun durch eine leichte Pleurareizung ohne oder mit einem unbedeutenden und deshalb unsichtbaren Lungeninfiltrat oder durch eine basale Bronchitis mit Schleimobturation von Bronchien (Obstruktionsatelektase) verursacht sein. Dass basale Atelektase sowohl auf die eine wie auf die andere dieser beiden Arten entstehen kann, ist seit langem bekannt. Zu einer sicheren Detaildiagnose konnte man natürlich in diesem Fall rein röntgenologisch nicht gelangen. Das klinische Bild und der Verlauf sprachen für eine Bronchopneumonia mit Pleuritis sicca.

Der angeführte Fall ist in mehreren Beziehungen interessant. Dass eine krankhafte Veränderung vorlag, zeigte sich beim Röntgen vor allem an der basalen Verschleierung und dem Nachschleppen des Zwerchfells. Diese beiden Symptome verschwanden, nachdem Pat. tief in Seitenlage geatmet hatte. Dasselbe wäre wahrscheinlich geschehen, wenn man Pat. auch in aufrechter Stellung forciert hätte einatmen lassen, denn so verhielt es sich in einem andern gleichartigen Fall. Es kann somit in gewissen Lungenfällen vom röntgendiagnostischen Gesichtspunkt aus unvorteilhaft sein, den Patienten vor der Untersuchung unrichtige Stellung im Bett einnehmen (mit der kranken Seite nach oben) oder ihn zu tief oder zu forciert atmen zu lassen, denn dadurch können für die Diagnose wertvolle Röntgensymptome, — ja manchmal die einzigen —, wie basale Atelektase und Nachschleppen des Zwerchfells, verschwinden oder undeutlich und schwer deutbar werden. *Man muss also in gewissen Fällen die Lungen sowohl vor wie nach einer kräftigen Ventilation untersuchen*, welch letztere am besten in Seitenlage mit der kranken Seite nach oben erfolgt.

Die Differentialdiagnose bei lamellärer Pleuritis

Lange hat man mit Fleischner geglaubt, die Diagnose Pleuritis stehe fest, wenn man einen deutlichen Randstreifen längs der lateralen oder hinteren-lateralen Thoraxwand gefunden habe. Dies ist jedoch nicht immer der Fall. So hat Knutsson 1932 nachgewiesen, dass die normale, auf der Innenseite der Rippen liegende dünne Muskelschicht, die Mm. intercostales interni und subcostales, die sich in gewissen Teilen des Thorax, vor allem hinten, befindet, ein an lamelläre Pleuritis erinnerndes Bild hervorrufen kann, dass aber mit dieser Fehlerquelle bei sagittaler Strahlenrichtung kaum zu rechnen ist, sondern fast ausschliesslich, wenn man das Bild in so schräger Projektion aufnimmt, dass hinten-lateral oder hinten liegende Thoraxteile randbildend werden. Er sagt ferner mit Recht, dass die schmale, dichte Grenzzone, die man oft an der Grenze zwischen den Lungenparenchym und einem Randstreifen antrifft, auf optischer Täuschung (Mach'sche Sinnestäuschung) beruht und nicht, wie Fleischner glaubt, Ausdruck einer Pleuraschwarte ist. Dies lässt sich leicht durch Winds Abdeckungsversuch zeigen.

Herrnheiser, Kubat und Neugebauer haben auf eine andere Fehlerquelle aufmerksam gemacht. Neugebauer stellte nämlich fest, dass oft, vor allem bei beleibten Personen, ein deutliches subpleurales Fettlager vorhanden ist, welches zwischen der 4. und 8. Rippe von der hinteren Brustkorbwand nach vorn in die Flanke und nicht selten weit über die vordere Axillarlinie reicht. Diese Fettschicht muss also ein an

lamelläre Pleuritis erinnerndes Bild auch bei gewöhnlichen, mit sagittaler Strahlenrichtung aufgenommenen Lungenbildern geben können. Die Fettschicht ist jedoch nicht von gleichmässiger Dicke, sondern besteht in Fettwülsten längs den Rippen (NEUGEBAUER). Diese Fettwülste, die bis zu $^1/_2$—1 cm dick sein können, erstrecken sich bisweilen mit einer dünneren Schicht eine kürzere oder längere Strecke über die unterhalb kaudalwärts liegenden Interstitien. Diese Fettleisten sind auf beiden Seiten symmetrisch ausgebildet. Durch Photographieren eines Lungenthoraxpräparates mit sichtbarem Randstreifen vor und nach dem Abpräparieren dieser Fettwülste unter Schonung der darunterliegenden dünnen Muskelbündel konnte nachgewiesen werden, dass der Randstreifen in diesen Fällen auf der Fettschicht beruhte. Zwischen dem Randstreifen und der Lunge fand KUBAT eine Verdichtungsrandlinie, die er nicht für eine optische Täuschung hielt, wie es KNUTSSON für seine Fälle von muskulärem Randstreifen nachgewiesen hat, sondern für den Ausdruck eines realen Substrates, nämlich der tangential getroffenen Pleuraduplikatur (Pleura parietalis und pulmonalis). Seine Ansicht dürfte meines Erachtens in der Hauptsache richtig sein, soweit es sich um diese Lungenpräparate mit ausgesprochener subpleuraler Fettschicht handelt, aber ausser der Pleuraduplikatur kann nach den Gesetzen für die Entstehung von Scheinlinien auch eine Scheinlinie zu dieser Verdichtungsrandlinie beitragen. KUBAT überschätzt sicher m. E. die Bedeutung dieser subpleuralen Fettschichten als Fehlerquelle bei der Diagnose »typische lamelläre Pleuritis», denn in den Fällen, wo eine echte solche Pleuritis konstatiert werden kann, findet sich bei sagittaler Strahlenrichtung in der Regel nur auf der einen Seite ein Randstreifen und daselbst ausserdem andere röntgenologische Pleuritiszeichen, wie interlobäre Streifen und Nachschleppen des Zwerchfells. Letzteres gilt oft auch, wenn eine doppelseitige lamelläre Pleuritis nachgewiesen wird (siehe unten). Ferner haben Verf. u. HJELM, wie oben bemerkt, festgestellt, dass die lamelläre Pleuritis, wenn sie auf freiem Exsudat beruht, mit veränderter Körperstellung an Dicke wechselt. Auch Beobachtungen von SCHÖNFELD sprechen dafür, dass eine subpleurale Fettschicht sehr selten bei sagittaler Strahlenrichtung das Bild einer lamellären Pleuritis gibt. Bei pathologisch-anatomischer Kontrolle zahlreicher Fälle von solcher Pleuritis fand er die Röntgendiagnose immer bestätigt, dagegen bestand in einzelnen Fällen eine Pleuritis trotz fehlendem Randstreifen. In dieselbe Richtung weist auch der Umstand, dass physiologische Randstreifen, die ein in gewissem Grade an doppelseitige lamelläre Pleuritis erinnerndes Bild liefern, an einem sehr grossen Material gewöhnlicher Lungenbilder äusserst selten nachgewiesen werden können. Vereinzelt hat Verf. allerdings doppelseitige dünne Begleitschatten gesehen, die wegen ihrer symmetrischen Beschaffenheit, ihrer

geringen Dichte, ihrer schwach gewellten Kontur, ihrer gegen den Sinus hin abnehmenden Dicke oder ihres Aufhörens einige Zentimeter oberhalb desselben sowie wegen freier Zwerchfellbewegung als eine anatomische Variation unbestimmter Art gedeutet worden sind. Möglicherweise hat es sich hier gelegentlich um Fettgewebe gehandelt (siehe unten). In einem der von HJELM u. Verf. veröffentlichten Fälle von Mantelpleuritis, die erst in Seitenlage mit der verdächtigen Seite nach unten sichtbar war, liegt vermutlich eine Fehldiagnose vor, die auf unserer damals noch unvollkommenen Kenntnis der oben besprochenen physiologischen Mantelschatten und einer dadurch bedingten mangelnden Sorgfalt bei Seitenlagerung des Patienten beruht. Es handelte sich hier jedoch wahrscheinlich um einen physiologischen Muskelrandstreifen. Die oben erörterten subpleuralen Muskel- bzw. Fettschichten muss man vor allem im Auge behalten, wenn das Lungenbild in schräger Projektion aufgenommen wird, weil diese Schichten hinten stärker entwickelt sind als in der Flanke und deshalb bei schräger Projektion leichter randbildend werden können. Hält man sich bloss diese Fehlerquellen beim Befund von Randstreifen gegenwärtig, so ist meiner Ansicht nach die Diagnose »lamelläre Pleuritis» in der Regel leicht (Weiteres hierüber unten).

Auch der Referent von KUBATS u. NEUGEBAUERS Arbeit (referiert im Zentralblatt f. d. ges. Radiologie 1934) überschätzt die differentialdiagnostische Bedeutung der an sich wertvollen Beobachtungen dieser Autoren, wenn er sagt: »Röntgenanatomische Untersuchungen haben ergeben, dass nur in solchen Fällen Begleitschatten auftreten, wo den Innenflächen der seitlichen Rippenabschnitte Fettwülste angelagert sind.» Hierzu ist er wahrscheinlich unter anderem verleitet worden durch die Zusammenfassung jener Forscher und durch den unzutreffenden Titel ihrer Arbeit: »Über die Bedeutung des Begleitschattens in der Seitenkrümmung der Thoraxwand (lamelläre Pleuritis)». Hält man das Referat und den Titel zusammen, so kann man leicht den Eindruck gewinnen, dass eine echte lamelläre Pleuritis eine seltene Erscheinung sei, aber das ist vermutlich nicht die Ansicht jener Autoren.

HERRNHEISER, der die Anregung zu der eben erwähnten Arbeit von K. und N. gegeben hat, hofft, durch fortgesetzte Untersuchungen Unterscheidungsmerkmale zwischen der echten lamellären Pleuritis und anderen, an sie erinnernden, aber normalen Bildern zu finden. Er geht davon aus, dass die subpleurale Fettschicht keinen ebenso dichten Schatten geben kann wie Bindegewebe und Pleuraexsudat, und schliesst daraus, man müsse gewisse pathologische und physiologische Begleitschatten an folgenden Merkmalen unterscheiden können: »Kleine Mantelexsudate, Schwarten und Muskulatur, die den Rippen angelagert sind, müssen gleichartige Bilder in Form eines dichten Begleitschattens ge-

ben, welcher dicht an die Rippen grenzt. Eine subpleurale Fettschicht dagegen ist bei normaler Pleura durch einen ganz feinen Streifen, einen Strichschatten, charakterisiert, der vom Knochenschatten durch eine schmale, helle (dem Fettpolster entsprechende) Zone getrennt ist.» Wenn sich zwischen der hellen Zone und der Lunge ein breiterer dichter Begleitschatten findet, muss dieser nach H. auf die Anwesenheit von Pleuraschwarten oder von dünnschichtigen Ergüssen deuten.

Die Schwierigkeit, diese normalen und pathologischen Zustände lediglich nach der Dichte und Dicke verschiedener Schichten von Begleitschatten voneinander zu unterscheiden, dürfte grösser sein, als H. glaubt. Es sei bloss daran erinnert, dass ein Begleitschatten stets nach der Lunge hin dichter wird, weil die Brustkorbwand und die röntgenabsorbierende Schicht nach innen dicker werden (FLEISCHNER) und weil, wie KNUTSSON mit Recht betont, an der Grenze zwischen der Lunge und einem Mantelexsudat bzw. der Lunge und Muskulatur immer eine dichte Scheinlinie entsteht. Eine solche Scheinlinie kann von sehr verschiedener Deutlichkeit und Breite sein, wovon sich Verf. bei Untersuchung vor allem in Seitenlage von vielen Mantelexsudatfällen überzeugen konnte. Verf. hat deshalb noch nach anderen Zeichen gesucht, an denen sich die pathologischen und physiologischen Randstreifen voneinander unterscheiden lassen, und führt nachstehend solche Unterscheidungsmerkmale an, von denen ein Teil bereits oben nebenbei erwähnt wurde oder früher von anderen Autoren beobachtet worden ist.

Wie unterscheidet man die echte Mantelpleuritis von einem physiologischen Mantelschatten, hervorgerufen durch Muskulatur oder Fettgewebe?

Die Lage und Form des Mantelschattens ist oft, wie schon KNUTSSON betont hat, ausschlaggebend für die Diagnose »Mantelpleuritis oder physiologischer muskulärer Mantelschatten», ebenso die Beweglichkeit des Zwerchfells. Die physiologischen Begleitschatten sind doppelseitig und symmetrisch; die Mantelpleuritis ist einseitig oder, falls doppelseitig, oft von verschiedener Dicke auf beiden Seiten. Die physiologischen Mantelschatten reichen meist bei aufrechter Stellung nicht bis zum Sinus hinab und werden nach unten schmaler. Sie treten oft bei sagittaler Strahlenrichtung nicht hervor, sondern in der Regel erst, wenn hinterelaterale Teile randbildend werden. Sie nehmen nach hinten an Dicke zu, doch ohne dort grössere Mächtigkeit zu erreichen. Das Zwerchfell bewegt sich frei, und der Sinus füllt sich normal. Der Pleuritismantel tritt meist schon bei sagittaler Strahlenrichtung hervor, nimmt aber gleichfalls nach hinten an Mächtigkeit zu, oft bedeutend. Er reicht in

der Regel in den Sinus phrenicocostalis hinab, welcher ausgefüllt ist, und das Zwerchfell schleppt nach. Er nimmt bei aufrechter Stellung oft etwas nach unten an Dicke zu, meist in der Nähe des Sinus. Wenn das Exsudat flüssig ist, wechselt es an Dicke mit der Atmungsphase (SCHIFFER und FLEISCHNER) sowie mit der Körperstellung (HJELM und Verf.). Der Pleuritismantel wird dann nämlich beim Ausatmen dicker als beim Einatmen und dicker, wenn die kranke Seite nach unten liegt, als bei aufrechter Stellung. Am schmalsten ist der Mantel, wenn die kranke Seite nach oben liegt, und kann dann ganz verschwinden. Diese Dickenschwankungen treten natürlich nicht auf bei Pleuraschwarten, subpleuralen Entzündungen und fibrinöser Pleuritis, ebensowenig bei physiologischen Randschatten.

Die lamelläre Pleuritis kann, wie bereits angedeutet, gelegentlich doppelseitig sein (z. B. bei akuter Pankreatitis), ist dann aber oft nicht auf beiden Seiten gleich ausgebildet, und häufig sieht man gleichzeitig deutliche interlobäre Beläge, eine bei freier Pleuritis äusserst gewöhnliche Erscheinung (SCHIFFER, FLEISCHNER u. a.). Bei beleibten Personen mit hochstehenden Zwerchfellkuppeln findet man oft horizontale derartige Streifen unmittelbar oberhalb der Zwerchfellkuppeln oder dieselben kreuzend (Verf. und HULTÉN). Bisweilen sieht man interlobäre Streifen vom Zwerchfell schräg in die Interlobärfurche des Lobus accessorius ausstrahlen, die nach dem Hilus gerichtet ist, oder in den vom Zwerchfell schräg nach aussen verlaufenden Teil der Furche zwischen dem oberen und unteren bzw. zwischen dem mittleren und unteren Lobus. Häufig findet man auch einen Belag zwischen dem oberen und mittleren Lappen.

Die lamelläre Pleuritis hat, wenn sie in flüssigem Exsudat besteht, eine gleichmässige Grenze gegen die Lunge. Normaliter hat die Lunge dagegen oft eine bis zu gewissem Grade ungleichmässige, gewellte Grenze gegen die Thoraxwand, indem sich die Interstitien bei stark intrapulmonalem Überdruck nach aussen wölben und umgekehrt bei ausgesprochenem intrapleuralem Unterdruck nach innen. Diese Ungleichmässigkeiten geben sich in der Regel auf gewöhnlichen Lungenbildern von Erwachsenen wenig zu erkennen, weil die Interstitien bei sagittaler Strahlenrichtung nicht von den Rippen freiprojiziert sind. Bei Kleinkindern wiederum haben die Rippen oft einen mehr horizontalen Verlauf, und deshalb sieht man bei ihnen häufig Teile der Lungenoberfläche in der Flanke mehr oder minder zwischen den Rippen freiprojiziert. Gleichartige Bilder kann man auch bei Erwachsenen erhalten, wenn man mit einer schrägen, geeigneten Strahlenrichtung photographiert, die sich leicht bestimmen lässt, indem man den Verlauf der Rippen auspalpiert. Bestehen ausgesprochene Fettleisten längs den Innenflächen der Rippen, was der Anatom NEUGEBAUER, wie oben bemerkt, als die typi-

sche Verteilung des subpleuralen Fettes beschreibt, so muss die Lungenoberfläche mehr oder minder wellenförmig werden; diese segmentale Wellenförmigkeit muss dann teils mit der Mächtigkeit der Fettleisten, teils mit dem intrapulmonalen Druck wechseln. Bei intrapulmonalem Überdruck muss eine solche Wellenförmigkeit am ausgesprochensten sein, weil sich die Interstitien, die keine oder nur eine dünne Fettschicht besitzen, dann nach aussen buchten, während die hohen Fettleisten an den Rippen sich nach wie vor nach innen wölben. Ein pulmonaler Überdruck kann dagegen bei flüssigem Exsudat nicht die Gleichmässigkeit der Grenzlinie beeinflussen, die der Exsudatmantel gegen die Lunge aufweist, wohl dagegen die Grenzlinie bei dünner pleuraler Schwarte oder Fibrinpelz sowie auch bei subpleuralem Muskelmantel. Diese letzteren Gebilde können sich bei intrapulmonalem Überdruck in gleicher Weise wie normale Interstitien ohne einen solchen pathologischen oder physiologischen Belag wölben, wenngleich etwas weniger je nach der grösseren oder geringeren Stütze, welche diese Gebilde den Interstitien verleihen.

Eine Fettschicht muss natürlich, wie HERRNHEISER hervorhebt, einen weniger dichten Schatten geben als ein Mantelexsudat oder eine Pleuraschwarte. Aber hier handelt es sich um Fettwülste, zwischen denen lufthaltige Lungenteile liegen; auf gewöhnlichen Lungenbildern muss deshalb die Dichte der Fettwülste gering erscheinen. Dies sowie der Umstand, dass die Fettschicht in der Flanke meist unbedeutend ist, vor allem ganz unten am Sinus, wo das Fett am leichtesten bei sagittaler Strahlenrichtung nachzuweisen wäre, dürften dazu beigetragen haben, dass an der hiesigen Abteilung unter Tausenden von Lungenbildern bisher keine Lunge mit einem subpleuralen Fettpolster angetroffen worden ist, das zu der Fehldiagnose lamelläre Pleuritis Anlass gegeben hätte.

Wenn sich ein Mantelexsudat zu einem dünnen subpleuralen Fettmantel gesellt, ist es meines Erachtens wahrscheinlich, dass sich die subpleurale Fettschicht noch schwerer auf dem Röntgenbild erkennen lässt, weil sich das Exsudat teilweise in den Rinnen zwischen den Fettleisten ablagert und das Fett infolge der Anwesenheit des entzündlichen Exsudats anschwillt und sich entzündet, so dass es stärker schattenbildend ist als normalerweise. Man erinnere sich bloss daran, wie sich die subperitoneale Fettschicht bei Peritonitis und Abszess verhält. Sie wird immer undeutlicher und kann fast unsichtbar werden (Verf.). Dazu kommt, dass auch ein Pleuraexsudat ohne Anwesenheit eines subpleuralen Fettmantels lateral weniger schattenbildend ist als medial, teils infolge der zylindrischen Form des Thorax, teils infolge der MACH'schen Scheinlinie an der Grenze gegen die Lunge, sowie, dass diese Scheinlinien, die sich bei allen physiologischen und pathologischen Mantel-

bildungen finden, unter dem Einfluss verschiedener Faktoren, unter anderem des Luftgehaltes der Lunge, an Deutlichkeit wechseln. Man kann deshalb nicht ohne weiteres aus dem Umstand, dass ein subpleuraler Mantel der einen oder anderen Sorte gegen die Peripherie hin durchsichtiger erscheint, auf die Anwesenheit von Fett schliessen, wie HERRNHEISER vermutet. Für die Differentialdiagnose »physiologische oder pathologische Mantelschatten?» wird man auf beweiskräftigere Symptome zurückgreifen müssen.

Nach dem Obengesagten ist es leichter, eine lamelläre Pleuritis mit freier Flüssigkeit zu erkennen als eine, die durch Schwarten und fibrinöse Pleuritis hervorgerufen ist. Aber in diesen beiden letzteren Fällen bieten das Nachschleppen des Zwerchfells auf der kranken Seite sowie ferner die Lage und das Aussehen der Schwarte (siehe oben) gute Anhaltspunkte für die Differentialdiagnose gegen physiologische Mantelschatten. Ausserdem ist natürlich oft das klinische Bild von grossem diagnostischen Wert (stechendes Gefühl, Reibegeräusch usw).

Handelt es sich um eine einseitige, seröse oder fibrinöse, Pleuritis, so besteht meist auf der kranken Seite eine Verschleierung des Lungenfeldes infolge der erschwerten Einatmung und wahrscheinlich auch infolge eines gleichzeitig relativ vermehrten Blutgehalts im Kapillargebiet der kranken Seite im Vergleich mit dem der gesunden (Verf.). Diese Symptome fehlen in der Regel bei physiologischen Mantelschatten.

ZUSAMMENFASSUNG

Um röntgenologisch ein kleines Pleuraexsudat nachweisen zu können, das bei gewöhnlicher Technik nicht oder nicht mit Sicherheit sichtbar ist, muss man die Lunge auch in Seitenlage mit der kranken Seite nach unten untersuchen, wobei, wie HJELM und Verf. früher nachgewiesen haben, oft ein deutliches Mantelexsudat hervortritt.

Die echte »lamelläre Pleuritis» lässt sich durch viele Zeichen, welche angeführt werden, von physiologischen Mantelschatten (subpleuralen Muskel- und Fettschichten) unterscheiden. Von den genannten Fehlerquellen ist der von KNUTSSON beschriebene muskuläre Mantelschatten entschieden die wichtigste.

Verf. zeigt, dass in gewissen Fällen von Bronchitis oder beginnender Bronchopneumonie mit Atelektase die vorhandenen Röntgensymptome (basale Verschleierung und Nachschleppen des Zwerchfells auf der kranken Seite) ganz verschwinden können, nachdem Pat. tief geatmet hat, namentlich wenn er dabei Seitenlage mit der kranken Seite nach oben einnimmt. Die Methode, in solchen Fällen sowohl im Sitzen wie im Liegen, und im letzteren Falle mit der kranken Seite sowohl nach unten wie nach oben, zu photographieren, kann, bei gleichzeitiger Berücksichtigung des klinischen Bildes, die Deutung der basalen Verschleierung (Pleuritis, Pneumonie, Atelektase oder eine Kombination dieser Erkrankungen?) in hohem Grade erleichtern.

SUMMARY

For the X-ray demonstration of small pleural exudates, the visualisation of which is either impossible or doubtful by means of the ordinary technique, examination of the lung should be made with the patient lying on his ill side, whereby a distinct exudate, as HJELM and the author have pointed out before, will in many cases become distinctly visible.

A true »lamellar pleuritis» can be distinguished from physiologic shadows (subpleural layers of muscular and fatty tissues) by a great many signs, which the author enumerates. Decidedly the most important of these sources of error is the muscular subpleural shadow described by KNUTSSON.

The author shows that the existing roentgenologic symptoms (veiled appearance at the base, and diminished mobility of the diaphragm on the ill side) can, in certain cases of bronchitis or incipient bronchopneumonia, disappear entirely after the patient has inhaled deeply, especially if he, at the same time, is lying on his side, with the ill side upwards. In such cases, roentgenography as well in sitting as in recumbent posture — the latter both with the ill side upward and downward — will greatly assist the interpretation of the basal veiling, and help to show whether the case is one of pleurisy, pneumonia, atelektasis, or perhaps a combination of any of these; whereby also the clinical picture must be taken into consideration.

RÉSUMÉ

Pour déceler par la radiologie un petit épanchement pleural, qui est douteux ou invisible au moyen de la technique ordinaire, l'examen des poumons doit être fait dans le décubitus latéral, le côté malade en bas; position dans laquelle souvent un exsudat en forme de manteau apparaît distinctement comme HJELM et l'auteur l'ont antérieurement montré.

La véritable »pleurite lamellaire» peut être séparée par de nombreux signes, qui sont énumérés, des ombres physiologiques en forme de manteau (les couches sous-pleurales musculaires et adipeuses). Des pièges en question l'ombre musculaire en forme de manteau décrite par KNUTSSON est sans contredit le plus important.

L'auteur montre que dans certains cas de bronchite ou de bronchopneumonie débutante accompagnée d'atélectasie les symptômes radiologiques existants (l'obscurité basale et une certaine immobilisation du diaphragme du côté malade) peuvent disparaître totalement après une respiration profonde, surtout si le patient est couché sur le côté sain. La méthode de photographier dans ces cas dans la position assise et dans la position couchée, sur le côté malade ainsi que sur le côté sain, peut considérablement faciliter l'interprétation de l'obscurité basale (pleurésie, pneumonie, atélectasie ou une combinaison de ces affections?), et à ce propos on doit avoir égard à l'image clinique.

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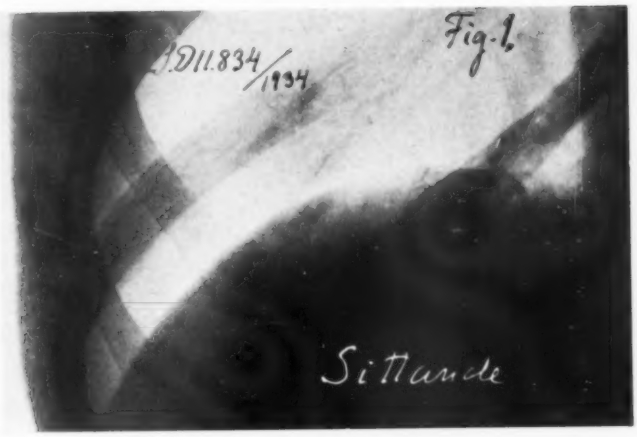

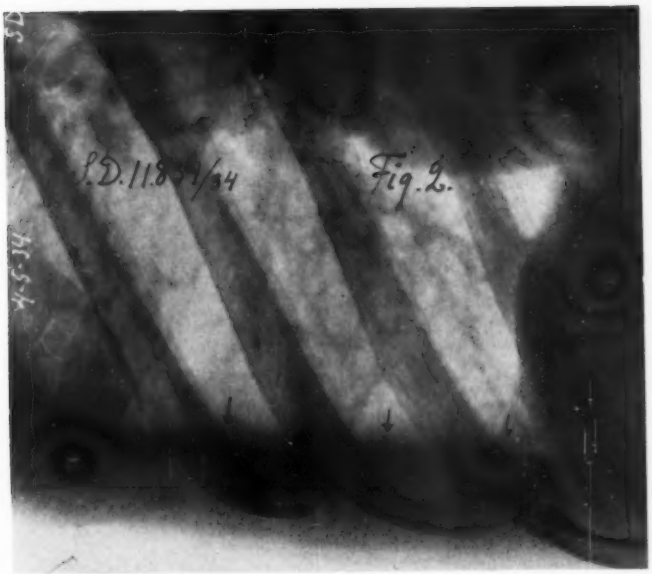

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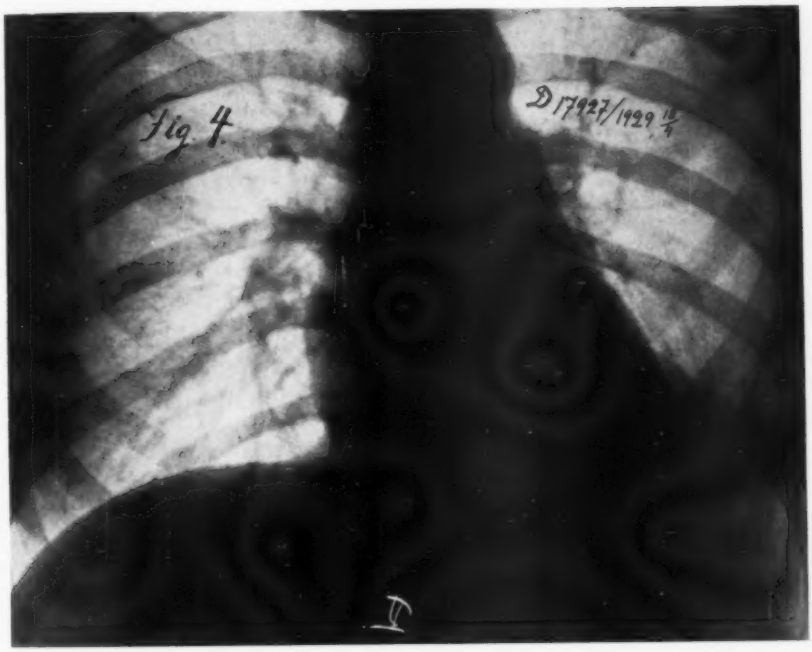

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THE DEPENDENCE OF THE BACK-SCATTERING OF ROENTGEN RAYS IN A PHANTOM ON FOCAL DISTANCE, QUALITY OF RADIATION AND FIELD SIZE[1]

by

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Introduction

Although considerable attention has been devoted to the question of the percentage back-scatter of roentgen rays at the surface of a scattering medium, the more general problem concerning the amount of scatter at various points within the scattering body has been relatively neglected. As this problem is by no means without interest, both from the physical point of view, and in its practical applications to roentgen therapy, a continuation of the work of THORÆUS (1) has been considered justifiable. In accordance with recent tendencies in therapy the investigations have been extended to much harder radiations. The convenient method of presentation developed by THORÆUS has been followed in toto. The true primary intensity at the focal distance F is taken to be unity with the scattering phantom removed. Then the true primary intensity at a depth d is written $I_P \times \delta m$, where I_P is obtained by applying the inverse square law to the relation $I_P = 1$ at $d = 0$, and δm is the transparency of the absorbing depth d for the particular radiation used. Denoting the total measured intensity by I_T, the scattered radiation is $I_S = I_T - I_P \cdot \delta m$. The ratio I_S/I_T constitutes a convenient measure of the amount of scattered radiation in terms of the total radiation.

With these definitions, the values of I_S/I_T for the central axis of the irradiated zone have been tabulated for different focal distances, qualities of radiation, and field sizes. The completely general proposition involving

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measurements off the central axis is too complex for treatment in a single paper.

Experimental Arrangements

A continuously evacuated roentgen tube of the type described by ALLIBONE and BANCROFT (2) was used as the source of radiation. The tube is provided with a gold anticathode and operates at constant potentials up to 250 K. V. at 10 m.a. The output is steady and reproducible within the limits of accuracy of measurement. The filtration effect of the steel wall of the tube sets a lower limit to the available quality at H.V.L. = 0.32 mm. Cu, consistent with the delivery of reasonable intensities. The upper limit, H.V.L. = 3.3 mm. Cu, is attained by a filter of (Tube wall + 1.05 mm. Sn + 0.4 mm. Cu + 1 mm. Al) at 250 K.V. As no radical differences were detected in the measurements at the same H.V.L. of radiations obtained by different combinations of voltage and filter, H.V.L. in Cu has been accepted provisionally as a sufficiently exact designation of quality.

The depth dose measurements involved were made with four standard commercial dosimeters. Three of the ionisation chambers were cylindrical and the fourth spherical, the diameters varying from 0.8 cm. to 1.8 cm. Parallelism of the chambers with the standard air-chamber over a very wide range of quality is claimed by the makers. No systematic difference was found in the responce of the four chambers in air between H.V.L. = 0.32 mm. Cu and 3.3 mm. Cu. Nevertheless, the measured depth doses were found to vary in a manner which could apparently be related to the chamber size. The figures finally chosen represent an attempted extrapolation to zero size. These results are to be published in detail elsewhere. The measuring phantom consisted of slabs of wax of unit density each 40 cm. × 40 cm. and of graded thicknesses totalling 35 cm. A preliminary comparison with measurements in a large water phantom ensured that no error was introduced in substituting the special wax for water. Wax was preferred mainly because two of the chambers were not suitable for extensive measurements in a fluid, but other advantages included more exact positioning at the zero level (no meniscus effect) and the possibility of measuring with the beam not in a vertical direction. The zero position was read with the chamber axis in the scattering surface (i. e. »half immersed»).

The measurements of the primary intensity in air were repeated with the anticathode, aperture, and chamber rotated as a whole through 90° on either side of the vertical position to direct the beam on to distant walls. The invariability of the intensity under these conditions established that no appreciable amount of scatter from surrounding objects was being

included. Moreover, rapid alternations of the surface readings with and without back-scatter could be made by rotating the beam and resetting the chamber without moving the heavy phantom. Estimations of surface back-scatter with the four chambers were reasonably consistent. Circular fields of diameters 5—20 cm. and rectangular fields from 6 × 4 cm. to 15 × 20 cm. were used. In order to simulate therapeutic conditions as closely as possible applicators lined with lead, copper, and aluminium (to absorb the lead characteristic radiation) and closed at the proximal end with a thin layer of wood were used to define the beam. The percentage back-scatter at the surface and the depth doses proved to be smooth functions of the area of the field provided that rectangles of elongation greater than 3: 2 were not included.

The half value layers in copper were measured with the smallest field, the distance between the chamber and the filters being at least 35 cm. The values of the transparency δm were taken from THORÆUS and the tables of GREBE and NITZGE (3) for the harder radiations, the two sources agreeing well over the common range.

Experimental Results

1. The dependence of I_S/I_T at any depth on focal distance

From the depth dose and surface back-scatter at F = 40, 60, 80 and 100 cm. for different radiations, I_S/I_T at depths down to 12 cm. has been calculated by the THORÆUS method. The results for H.V.L. = 1.5 mm. Cu and four fields are collected in Table 1. It is immediately apparent that for each setting of A and d, I_S/I_T is unaltered by the change in F. Similar results are shown in Table II for the extreme qualities to demonstrate that the independence of I_S/I_T on F is a general property. The physical interpretation of this observation is evidently that the scattering block acts on the beam which would exist without scatter in a constant manner. This operational effect may be turned to good account in the construction of complete isodose curves for the distribution of radiation throughout the scattering medium. The accurate determination of these curves is a laborious process, particularly if it is undertaken for a number of fields at various focal distances. It now becomes possible to deduce the complete set of curves from measurements at one focal distance, combined with a knowledge of the surface back-scatter for the fields used, by proceeding as follows:

From the set of measurements at focal distance F, I_T and I_P may be evaluated for any point in the phantom. For the corresponding point at the new focal distance F′, I'_P may be written down at once, and I'_T

Table I

H.V.L. = 1.5 mm. Cu.

	Depth cm.	F = 40 cm.			F = 60 cm.			F = 80 cm.			F = 100 cm.		
		I_T	I_s	I_s/I_T	I_T	I_s	I_s/I_T	I_T	I_s	I_s/I_T	I_T	I_s	I_s/I_T
	0	1.135	.135	.12	1.135	.135	.12	1.135	.135	.12	1.135	.135	.12
	1	1.07	.27	.25	1.08	.27	.25	1.09	.27	.25	1.10	.275	.25
	2	.93	.30	.32	.955	.295	.31	.965	.295	.31	.97	.30	.31
A = 19.6	4	.68	.26	.38	.715	.275	.38	.745	.285	.38	.75	.29	.38
cm.²	6	.49	.22	.45	.53	.24	.45	.55	.25	.45	.56	.25	.45
	8	.35	.17	.48	.39	.185	.49	.41	.20	.49	.42	.205	.49
	10	.26	.14	.54	.29	.15	.52	.305	.155	.51	.315	.155	.51
	12	.19	.11	.58	.205	.115	.56	.22	.12	.55	.225	.12	.55
	0	1.37	.37	.27	1.37	.37	.27	1.37	.37	.27	1.37	.37	.27
	1	1.32	.52	.39	1.34	.535	.39	1.36	.54	.39	1.365	.54	.395
	2	1.17	.54	.46	1.22	.56	.46	1.24	.57	.46	1.24	.57	.46
A = 80	4	.93	.51	.55	.99	.55	.555	1.01	.55	.55	1.02	.56	.55
cm.²	6	.73	.46	.63	.80	.51	.64	.805	.505	.63	.81	.50	.62
	8	.57	.39	.69	.64	.44	.69	.645	.435	.68	.65	.445	.68
	10	.42	.30	.71	.49	.35	.71	.50	.35	.70	.51	.35	.69
	12	.32	.24	.75	.37	.28	.75	.38	.28	.74	.39	.29	.74
	0	1.41	.41	.29	1.41	.41	.29	1.41	.41	.29	1.41	.41	.29
	1	1.41	.61	.43	1.405	.59	.42	1.41	.59	.42	1.41	.585	.42
	2	1.29	.66	.51	1.29	.63	.49	1.30	.63	.49	1.30	.63	.49
A = 150	4	1.05	.63	.60	1.08	.64	.59	1.10	.64	.58	1.12	.66	.59
cm.²	6	.835	.565	.68	.89	.60	.68	.92	.62	.68	.94	.63	.68
	8	.65	.47	.725	.71	.515	.73	.735	.525	.72	.74	.525	.72
	10	.51	.39	.76	.56	.42	.75	.57	.42	.74	.585	.425	.74
	12	.395	.315	.795	.43	.34	.795	.445	.345	.78	.45	.345	.77
	0	1.52	.52	.34	1.52	.52	.34	1.52	.52	.34	1.52	.52	.34
	1	1.52	.72	.47	1.52	.70	.46	1.52	.70	.46	1.52	.70	.46
	2	1.41	.78	.55	1.42	.76	.54	1.42	.75	.53	1.43	.76	.54
A = 300	4	1.19	.77	.65	1.23	.79	.64	1.23	.77	.63	1.26	.80	.64
cm.²	6	.97	.70	.72	1.03	.74	.72	1.03	.73	.71	1.05	.74	.71
	8	.79	.61	.77	.85	.65	.77	.85	.64	.76	.875	.66	.76
	10	.64	.52	.81	.68	.54	.80	.70	.55	.79	.72	.56	.79
	12	.51	.43	.84	.56	.47	.84	.57	.47	.83	.57	.47	.83

Table I. The independence of I_s/I_T on focal distances at H.V.L. = 1.5 mm. Cu. Values of δm and the depth doses can be calculated from the columns given.

may be calculated from the relation $\frac{I'_T}{I'_P} = \frac{I_T}{I_P} = \frac{\delta m}{(I - I_s/I_T)}$ which is constant for corresponding points. The values of I'_T can then be translated into the new set of isodose curves. A complication is introduced, especially at large depths, by the change in the geometric width of the beam. Ex-

Table II

a) H.V.L. = 0.32 mm. Cu. $A = 19.6$ cm².

Depth cm.	F = 40 cm.			F = 60 cm.			F = 80 cm.			F = 100 cm.		
	I_T	I_S	I_S/I_T	I_T	I_S	I_S/I_T	I_T	I_S	I_S/I_T	I_T	I_S	I_S/I_T
0	1.235	.235	.19	1.235	.235	.19	1.235	.235	.19	1.235	.235	.19
1	1.21	.49	.40	1.23	.49	.40	1.23	.49	.40	1.235	.48	.39
2	1.06	.52	.49	1.08	.525	.49	1.10	.535	.49	1.12	.55	.49
4	.77	.46	.60	.79	.465	.59	.82	.48	.59	.84	.50	.60
6	.545	.365	.67	.58	.38	.66	.61	.40	.66	.625	.415	.665
8	.37	.26	.705	.415	.29	.70	.43	.30	.70	.45	.31	.69
10	.26	.19	.73	.30	.22	.73	.32	.23	.72	.335	.245	.73
12	.19	.15	.79	.22	.17	.775	.23	.18	.78	.24	.19	.78

b) H.V.L. = 3.3 mm. Cu. $A = 19.6$ cm².

Depth cm.	F = 40 cm.			F = 60 cm.			F = 80 cm.			F = 100 cm.		
	I_T	I_S	I_S/I_T	I_T	I_S	I_S/I_T	I_T	I_S	I_S/I_T	I_T	I_S	I_S/I_T
0	1.075	.057	.07	1.075	.075	.07	1.075	.075	.07	1.075	.075	.07
1	1.03	.215	.21	1.05	.215	.205	1.05	.215	.205	1.06	.22	.21
2	.925	.24	.26	.955	.25	.26	.97	.255	.26	.97	.25	.26
4	.68	.215	.32	.73	.235	.32	.75	.24	.32	.755	.235	.31
6	.50	.19	.38	.55	.21	.38	.575	.22	.38	.585	.22	.38
8	.375	.155	.415	.41	.17	.415	.44	.185	.42	.455	.185	.405
10	.28	.13	.465	.32	.15	.47	.34	.16	.47	.35	.16	.46
12	.21	.11	.52	.245	.125	.51	.26	.13	.50	.27	.135	.50

Table II. The independence of I_S/I_T on focal distance at the extreme qualities.

periment shows, however, that suitable interpretation of »corresponding points» obviates the difficulty. If the central axis and two intersecting axes at right angles in the surface be chosen as axes of co-ordinates, the point in the second system corresponding to (d, x, y) in the first becomes simply (d, kx, ky) where $k = \frac{F\ (F' + d)}{F'\ (F + d)}$. This represents, in general, quite a small correction. Outside the geometric beam I_P and I'_P are actually zero but the method may be applied with success by using symbolically the values that would exist with the limiting aperture removed.

The Tables I and II exhibit a small reduction in I_S/I_T for the greater depths as F is increased. This is presumably due to the reduction in the total irradiated volume. There is, moreover, a slight increase in I_S/I_T

Table III

Quality	I	II	III	IV	V	VI
H.V.L. mm. Cu.	0.32	0.8	1.5	1.8	2.54	3.3

$\frac{I_S}{I_T}$ at $A = 19.6$ cm²

Depth cm.	I	II	III	IV	V	VI
0 . .	.19	.195	.12	.105	.10	.07
1 . .	.40	.35	.25	.24	.23	.21
2 . .	.49	.41	.32	.285	.27	.26
4 . .	.60	.48	.38	.375	.345	.32
6 . .	.67	.54	.45	.44	.42	.38
8 . .	.70	.58	.48	.48	.47	.415
10 . .	.73	.63	.54	.53	.50	.465
12 . .	.79	.66	.58	.57	.55	.52

$\frac{I_S}{I_T}$ at $A = 80$ cm²

Depth cm.	I	II	III	IV	V	VI
0 . .	.31	.305	.27	.21	.20	.18
1 . .	.50	.40	.33	.355	.33	.315
2 . .	.60	.53	.46	.41	.40	.38
4 . .	.70	.61	.55	.53	.50	.46
6 . .	.77	.68	.63	.60	.57	.54
8 . .	.81	.73	.69	.66	.62	.58
10 . .	.83	.775	.71	.705	.655	.63
12 . .	.87	.805	.75	.74	.695	.675

$\frac{I_S}{I_T}$ at $A = 150$ cm²

Depth cm.	I	II	III	IV	V	VI
0 . .	.345	.335	.29	.26	.245	.23
1 . .	.52	.49	.43	.41	.38	.36
2 . .	.62	.57	.51	.475	.46	.43
4 . .	.73	.67	.60	.58	.56	.52
6 . .	.80	.73	.68	.66	.625	.60
8 . .	.84	.77	.725	.71	.68	.645
10 . .	.86	.81	.76	.76	.72	.70
12 . .	.89	.84	.79	.79	.755	.745

$\frac{I_S}{I_T}$ at $A = 300$ cm²

Depth cm.	I	II	III	IV	V	VI
0 . .	.41	.39	.34	.32	.29	.275
1 . .	.58	.535	.47	.46	.42	.41
2 . .	.68	.62	.55	.52	.51	.48
4 . .	.78	.715	.65	.63	.61	.58
6 . .	.83	.77	.72	.71	.68	.66
8 . .	.87	.82	.77	.765	.73	.71
10 . .	.89	.85	.81	.805	.76	.755
12 . .	.92	.88	.84	.84	.805	.80

Table III. The variation of I_S/I_T with quality of radiation.

at d = 0 as F increases, produced by the slightly increased I_P values at neighbouring points, but this only affects the third figure, which has not been included in the tables.

2. The variation of I_S/I_T at any depth with quality

The values of I_S/I_T at depths down to 12 cm. for four field sizes and six qualities of incident radiation are set out in Table III. It follows from the previous section that the results will apply equally to any focal distance. The table shows at once that there is a diminution in I_S/I_T at

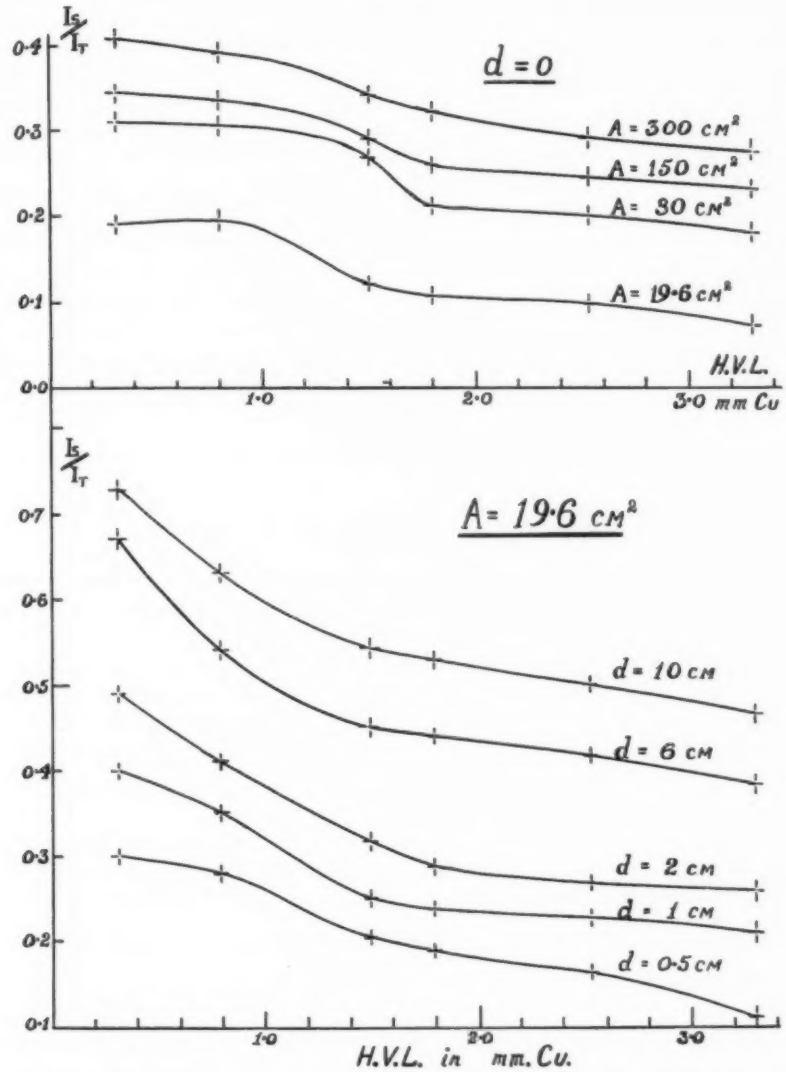

Fig. 1. Typical curves of the variation of I_S/I_T with quality of radiation.

any depth with increasing hardness of incident radiation, over the range considered. The mode of variation with H.V.L. is more readily seen from a graphical representation and a few typical curves are given in

Fig. I. All the curves for depths greater than 1 cm are of the same general shape, viz. a rapid fall of I_s/I_T between the qualities I and III with a subsequent slower diminution. This type of curve is to be expected qualitatively from the nature of the scattering processes involved. As the effective wave length of the beam decreases the scattering coefficients and the relative amounts scattered at different angles change in the direction of decreasing I_s/I_T much more rapidly at first than the gain due to increasing transparency of the phantom with respect to the scattered rays. The curves for $d = 0$ seem to be of a different type and indicate rather a sharp fall of I_s/I_T between H.V.L. = 1.1 mm. Cu and 1.8 mm. Cu, with only slow changes in the other regions investigated. This special variation persists to a depth of about 0.5 cm. and is presumably due to the fact that the superficial layers can only collect scattered rays which have been sent back at angles greater than 90°. The dependence of this radiation on quality is, of course, different from that of the more general scatter at deeper points of the phantom.

3. The dependence of I_s/I_T on the field size

It is self evident that for each value of d, the back-scatter at a point on the central axis must increase as the field size A increases. The precise mode of increase may perhaps merit closer study and for this purpose it is convenient to consider I_s, rather than I_s/I_T. Some values for $d = 0$ and $d = 10$ are set out in Table IV. Equal increments of A have been chosen, representing approximately equal increments in the irradiated volume. Under these conditions the contributions to the scatter at the central axis should be given by a summation of terms of the type $\frac{\delta m}{r^2} f(\theta)$, neglecting multiple scattering. r is the distance of a scattering point from the axial point considered, δm the transparency of the scattered radiation along this path, and $f(\theta)$ takes account of the relative scattering power in this direction. As the field size is increased $\frac{1}{r^2}$ and δm will obviously decrease, and on the whole θ will tend more nearly to 90° giving a reduction in $f(\theta)$ over the range $\lambda e = 0.08$ Å to 0.24 Å. Consequently for equal increments in the scattering volume one would expect rapidly falling contributions to the total scatter. This is qualitatively the case at $d = 0$ for Qual. VI, but for Qual. III the increments above $A = 100$ are approximately constant, and for Qual. I, there is even some indication of a rise in ΔI_s above $A = 150$. It is unwise to base too many deductions on the small experimental values of ΔI_s but it may be pointed out that the discrepancy between theory and experiment could be accounted for

Table IV

$d = 0$ cm.

Field size cm²	Qual. I.		Qual. III.		Qual. VI.	
	I_s	Increment ΔI_s	I_s	Increment ΔI_s	I_s	Increment ΔI_s
0	0	—	0	—	0	—
50	.37	.37	.30	.30	.155	.155
100	.47	.10	.38	.08	.25	.095
150	.515	.045	.41	.03	.31	.06
200	.575	.06	.45	.04	.325	.015
250	.625	.05	.485	.035	.335	.01
300	.695	.07	.515	.03	.34	.005

$d = 10$ cm.

Field size cm²	Qual. I.		Qual. III.		Qual. VI.	
	I_s	Increment ΔI_s	I_s	Increment ΔI_s	I_s	Increment ΔI_s
0	0	—	0	—	0	—
50	.29	.29	.24	.24	.20	.20
100	.375	.085	.33	.09	.285	.085
150	.43	.055	.39	.06	.345	.06
200	.48	.05	.435	.045	.39	.045
250	.53	.05	.48	.045	.425	.035
300	.58	.05	.52	.04	.46	.035

Table IV. The increments of I_s for equal increments of field size.

by the existence of multiple scattering. Experiments to determine the amount of multiple scatter are at present in progress.

Discussion

1. Physical

The values of I_s/I_T differ from those of some other writers, being for the most part higher and showing a steady decrease as the radiation hardens. These differences must be ascribed solely to the different values of the percentage back-scatter at $d = 0$, since the depth dose figures agree tolerably well. As regards the surface values the serious discrepancies between the results of various observers presumably arise from the different experimental conditions and types of ionisation chambers used.

An analysis of these effects is beyond the scope of the present paper. It is interesting to note, however, that QUIMBY (4) and collaborators, employing a widely different technique have obtained results in surprisingly close agreement with those of the present writer. Preliminary calculations based on scattering formulae also seem to support, qualitatively, the dependence of I_S/I_T on type of radiation derived in this series of experiments.

2. Applications to therapy

A number of points of interest in deep therapy arises from the measurements of I_S/I_T. In the first place the dose at a depth in the phantom receives a far greater contribution from back-scatter than might be supposed. Even with a field as small as $A = 19.6$ cm. and at a normal H.V.L. $= 1.5$ mm. Cu, scatter at 10 cm. deep constitutes 54 % of the total radiation. At $A = 300$ the contribution has risen to 81 %. It follows that in the application of the rays to the human body, the presence of bone masses or air cavities may have an appreciable influence on the dose delivered to a tumour as compared with that calculated from isodose charts. Hence extensive measurement of the radiation at various points of a cadaver or fairly complete models of the body might profitably be undertaken as an aid to more exact dosage.

The rapid diminution of I_S/I_T in the superficial layers between H.V.L. $= 1.1$ mm. Cu and 1.8 mm. Cu offers suitable conditions for an examination of the possible variation of erythema with quality of radiation, a problem which does not yet appear to have been satisfactorily solved. In going to the harder of these two radiations not only is the primary hardness increased but advantage is taken of the notable decrease in back-scatter, which must necessarily be of a softer character. The average composition of the radiations in the first 5 mm. should therefore be quite different. Furthermore, with a roentgen ray set operating at 250 K.V. it is easily possible to obtain the two radiations at equal intensity and the range is so limited that errors in dosimetry are not likely to be important.

Increase of field size produces a less rapid increase of I_S/I_T for the hard radiation, in accordance with the increased forward concentration of the scattered radiation. The cut-off at the edge of the beam is therefore better defined for the hard radiation. This may prove to be a valuable asset of high voltage radiation, especially where narrow fields have to be directed just to miss vital structures. Reduced scattering out of the main beam is automatically combined with increased homogeneity in it.

The application of the results to the construction of isodose curves has already been described.

SUMMARY

Values of the back-scattering coefficient I_S/I_T of roentgen rays from H.V.L. = 0.32 — 3.3 mm. Cu are given for different focal distances, field sizes, and depths in a scattering block. I_S/I_T at any depth is independent of the focal distance and decreases steadily with increasing hardness of radiation. Therapeutic applications are briefly mentioned.

ZUSAMMENFASSUNG

Die Werte des Rückstreuungskoeffizients I_S/I_T der Röntgenstrahlen von H.W.S. = 0.32 — 3.3 mm. Cu werden für verschiedene Brennweiten, Feldgrössen und Tiefen in einem zerstreuenden Phantom gegeben. I_S/I_T in irgend einer Tiefe ist von der Brennweite unabhängig und vermindert sich beständig mit der zunehmenden Härte der Strahlung. Heilkräftige Anwendungen werden kurz erwähnt.

RÉSUMÉ

Les valeurs de la proportion, I_S/I_T de rayonnement diffusé au rayonnement total des rayons de roentgen de l'épaisseur de demi-valeur 0.32— 3.3 mm. Cu sont données pour des distances focales différentes, des dimensions du champ et des profondeurs dans un bloc de cire. I_S/I_T à n'importe quelle profondeur est indépendante de la distance focale et diminue régulièrement à mesure que la dureté du rayonnement s'augmente. On a parlé en peu de mots des applications thérapeutiques.

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PROF. H. LAURELL)

LA STRATIFICATION DES LIQUIDES OPAQUES DANS L'UROGRAPHIE[1]

Note complémentaire

par

S. Ribbing, Med. lic.

(Tabula CI)

Dans un article de cette revue (Vol. XIV) l'auteur a exprimé l'opinion suivante: »Il est vrai que juste au commencement de l'aflux de l'urine opaque au bassinet pendant la pyélographie par injection intraveineuse on peut remarquer une certaine inégalité dans le remplissage, mais sur le plus haut point de l'aflux, l'urine qui ne contient pas de contraste a presque complètement quitté le bassinet. Celui-ci a alors été rempli d'urine opaque qui a accoulé par une quantité de canaux fins dans les parois du bassinet, ce qui doit aussi favoriser un mélange homogène. Aussi la tendance de stratification n'est pas du tout aussi grande que dans la pyélographie rétrograde, ce qu'on constate par une expérience *in vitro* . . . . .»

A cause de l'expérience augmentée de la pyélographie par injection intraveineuse l'auteur se voit dans la nécessité de corriger son opinion sur quelques points. Il s'est montré à différentes reprises que, dans l'urographie par injection intraveineuse, l'urine opaque du bassinet peut se stratifier sous l'urine qui ne contient pas de contraste sans mélange notable avec celle-ci. Il est vrai que cette stratification est moins fréquente et peut-être aussi moins apparente que dans la pyélographie rétrograde, mais parfois elle se montre en complète évidence. Tel était par exemple l'état des choses dans le cas d'hydronéphrose causée par une bride vasculaire, illustré ci-dessous. (Vérification opérative par le Doc. SCHILDT à la Clinique Chirurgique de cet hôpital.)

La figure 1 est une radiographie prise en décubitus dorsal 35 minutes après l'injection intraveineuse de 20 cc. de perabrodil. Elle ne montre qu'un nombre de calices fortement dilatés. — La figure 2 est prise quand le malade s'est ensuite tourné en décubitus ventral et montre une opacité dans le bassinet, qui est en grande partie extra-rénal, mais aucune opacité dans les calices visibles sur la figure 1. — L'urine opaque montra donc

[1] Remis à la Réd. le 7 juin 1935.

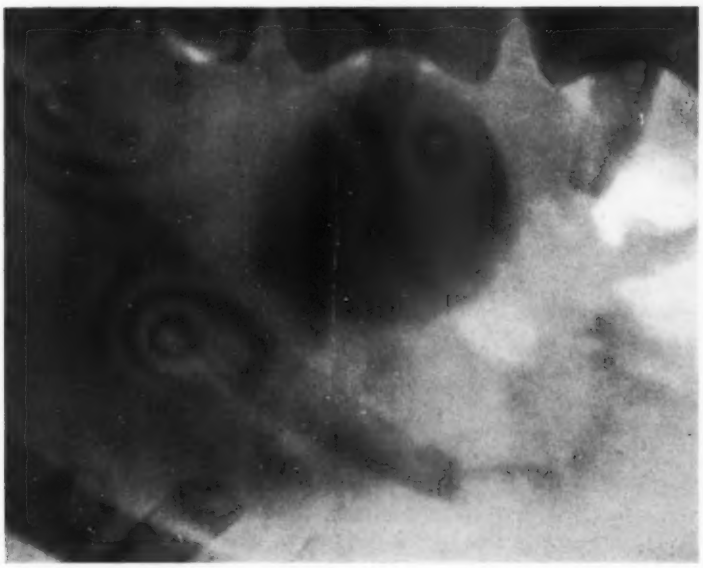

Fig. 2.

Fig. 1.

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dans ce cas une tendance si faible de se mélanger avec l'urine qui ne contenait pas de contraste que ces deux liquides n'ont pratiquement fait que de changer de place quand le malade s'est tourné.

Je me vois donc dans la nécessité de corriger mon opinion de la stratification de l'urine opaque, en notant que la source d'erreurs dans l'interprétation des pyélographies qui est causée par la tendance de stratification du liquide opaque sous l'urine stagnante dans le bassinet existe aussi, à certaines conditions, dans l'administration intraveineuse du liquide opaque.

Il est encore à remarquer que dans la pyélographie rétrograde on peut tirer profit de la tendance de stratification du liquide opaque pour éclaircir les conditions anatomiques de *l'uretère* dans les cas où l'uretère ne se remplit pas de liquide opaque par la technique ordinaire. A l'injection du liquide opaque par la sonde urétérique, on se voit souvent dans l'impossibilité de remplir de contraste le bassinet aussi bien que l'uretère en décubitus dorsal, à cause des douleurs du malade et à cause des risques qui existent à injecter une trop grande quantité de liquide opaque. La méthode indiquée par CHEVASSU (recommendée par HELLSTRÖM dans la littérature suédoise) de faire la pyélographie à l'aide d'une pointe de sonde en forme d'olive qui obture l'embouchure de l'uretère me semble condamnable à cause des risques d'un reflux pyélo-veineux par une trop forte pression dans l'uretère et le bassinet. Ces risques ont été agrandis après l'introduction de solutions opaques modernes et moins irritantes; elles augmentent naturellement encore, si on donne un injection de morphine avant la pyélographie. On doit au contraire, selon une opinion répandue, *se servir d'une sonde si fine* que l'écoulement à la vessie peut se faire avec une relative facilité à côté de la sonde. Il faut considérer la provocation d'une reflux pyélo-veineux comme un accident, dont les risques, surtout quand l'urine est infectée, ne doivent pas être négligés.

Quand le bassinet se montre complètement ou partiellement opaque tandis que l'uretère est invisible, on peut obtenir une opacité de ce dernier en retournant le malade en décubitus ventral. En raison de la position ventrale de l'uretère devant le muscle psoas, le liquide opaque descend dans l'uretère en le remplissant, tandis que l'urine qui ne contient pas de contraste remonte dans le bassinet. Si on éloigne la sonde urétérique dans cette position et si on prend une radiographie immédiatement, on obtient souvent de bonnes images de l'uretère. Les bulles d'air, qui peuvent être entrées à l'injection, passent d'une part au bassinet, d'autre part à la partie vésicale de l'uretère. En prenant deux ou plusieurs images pendant le videment de l'uretère on peut se garantir contre le risque de prendre des bulles d'air pour des calculs urétériques non imperméables aux rayons, dans les cas où une telle erreur serait possible.

Des images de l'uretère de ce genre sont faciles à obtenir dans presque toutes les pyélographies rétrogrades (si pour une cause ou une autre le contraste ne se vide pas trop promptement dans la vessie). Pour que le malade puisse se retourner en décubitus ventral avec facilité et sans douleurs, le cystoscope doit être éloigné après que la sonde urétérique a été placée, ce qui ne présente généralement aucune difficulté si une partie assez grande de la sonde est introduite dans la vessie. — On pourrait sans doute aussi obtenir des images opaques de l'uretère même en décubitus dorsal en se servant d'une solution opaque avec un poids spécifique plus léger (correspondant à l'emploi du lipiodol ascendant dans la myélographie.) Je ne trouve cependant pas qu'une telle solution opaque soit nécessaire pour l'urétérographie.

Ce que nous avons noté ici concernant le remplissage de contraste de l'uretère en décubitus ventral dans la pyélographie rétrograde, peut aussi être valable, dans certains cas, pour la pyélographie par injection intraveineuse. Mais il est ici moins fréquent qu'on n'obtienne pas déjà en décubitus dorsal une opacité des uretères.

RÉSUMÉ

L'auteur attire l'attention sur la stratification de l'urine opaque dans l'urographie par injection intraveineuse et sur la facilité d'obtenir une opacité de l'uretère dans la pyélographie rétrograde en retournant le malade en décubitus ventral. Cette dernière méthode devrait tenir lieu de l'urétéro-pyélographie d'après CHEVASSU, qui n'est pas sans danger.

SUMMARY

The author shows how the contrast-mixed urine in intravenous urography is stratified in a layer at the bottom of the renal pelvis and the easy way in which to get the ureter contrast-filled in retrograde pyelography by laying the patient in ventral position. This last method is to be preferred to the uretero-pyelography after CHEVASSU which is not quite harmless.

ZUSAMMENFASSUNG

Verf. macht auf die Schichtbildung von kontrasthaltigem Harn bei intravenöser Urographie, ebenso auf den Vorteil bei der retrograden Pyelographie den Ureter mit Kontrast dadurch zu füllen, dass Pat. in Bauchlage gewendet wird, aufmerksam. Diese Methode sollte der nicht ungefährlichen Uretero-Pyelographie nach CHEVASSU vorgezogen werden.

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SOME EFFECTS OF THE GAMMA RAYS OF RADIUM ON THE DEVELOPING CHICK EMBRYO[1]

I. The dependence of the delayed lethal dose on the age of embryo

II. The recovery and development of chick embryos after irradiation at various ages

by

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Part I

Introduction

Various investigations (1, 2, 3, 4, 5), have recently been carried out on the effect of the gamma rays of radium on living chick tissues grown »in vitro». This work necessarily deals with the »direct effects» of radiation on living cells. The present communication describes an extension of the work to the more complex conditions of growth in the presence of a circulation.

Some preliminary experiments indicated that the sensitivity of the developing chick embryo to gamma rays, as measured by the lethal dose, was in some way dependent upon its age at the time of irradiation. It was therefore decided to study this dependence using embryos of from 1 to 6 days incubation.

Biological Material

Some 10 dozen eggs were used, the majority from pure bred White Leghorn stock, but a few were from Rhode Island Red fowls when the others were not available. Before irradiation, the eggs were removed in pairs from the ordinary incubator and placed, with the long axis hori-

[1] Submitted for publication April 24th, 1935.

zontal, in holes on a specially constructed turn-table contained in a large, electrically heated, water jacketed incubator constantly maintained at 37—39° C. The air was kept moistened by means of dishes of water inside the incubator.

The eggs were transilluminated by reflected light so that the actual position of the embryo could be clearly seen. It was found that when an egg of 1 or 2 days incubation was left in position for a few seconds the embryo always floated to the top surface of the egg. In those of 3 to 6 days incubation, the embryo is fixed in position but readily located in the upper half of the egg.

Radiological Technique

The finite size of the embryos that were to be irradiated made it necessary to provide a distribution of radium such that the embryos

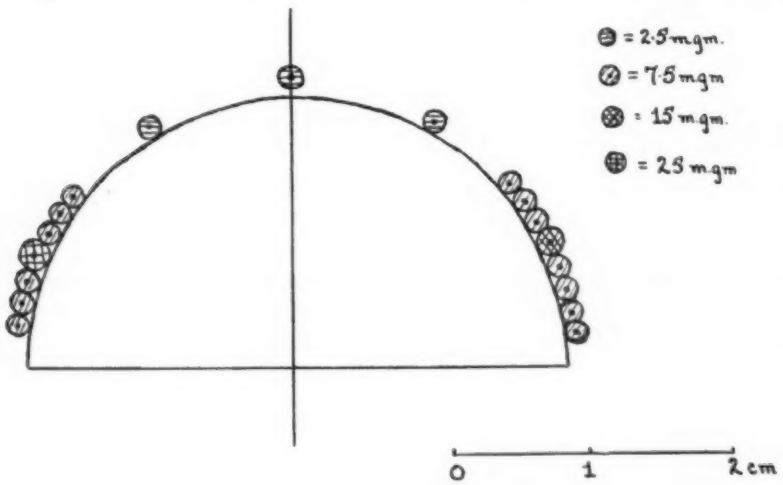

Figure 1. Arrangement of Radium Needles.

would lie, as far as possible, in a fairly uniform field of gamma radiation. An added difficulty was the irregular movement of the older embryos within the egg which necessitated a larger field of uniform intensity than that occupied by the embryo itself.

The actual arrangement of radium needles is shown in Figure 1, the design being restricted, of course, by the needles available. The figure represents a section across the common »equator» of the nedles, which were of four kinds, viz:

25 mgm radium element; active length 17.5 mm; filter 0.5 mm Platinum.
15 mgm radium element; active length 11.5 mm; filter 0.5 mm Platinum.
7.5 mgm radium element; active length 16.0 mm; filter 0.3 mm Platinum.
2.5 mgm radium element; active length 11.5 mm; filter 0.6 mm Platinum.
145 mgm of radium element was used in all.

The needles were mounted by means of sealing wax on to a semicircular arch of wood, the size of which was determined by taking the diameter across the shorter axis of an average size egg as 4.0 cm. This needle carrier was fitted with two slotted supports that allowed of a vertical movement for fitting the arrangement tightly over and as close to as possible, the eggs to be irradiated.

In carrying out an irradiation the egg was transilluminated and the arch placed tightly over it so that the embryo was centred as accurately as possible with respect to the needles. In every such experiment a similar egg was kept in the same incubator as a control and was protected from any radiation by a distance of at least 20 centimetres and a lead screen one inch in thickness. After the eggs had been incubated for a further 24 hours from the end of the irradiation they were opened and examined macroscopically.

The object of the experiments was to determine the exposures required to produce, in 1—6 day embryos, a lethal effect within 24 hours. At least 6 eggs were irradiated for each exposure period and each egg had a corresponding control. The cessation of the heart beat was taken as evidence of death.

Physical Determination of the Distribution of Radiation Intensity

To obtain an indication of the *distribution* of intensity due to the radium arrangement described above, the method of mathematical calculation was used. This method seems to be quite justified by recent work on the agreement between calculated and measured intensities due to radium sources (5, 6).

The unit adopted was the intensity-milli-curie (Imc) used by SIEVERT (7, 8, 9) and defined as the intensity due to the radiations at a point distant 1 cm. from a 1 mgm. point source of radium screened by 0.5 mm. platinum.

By applications of formulae developed by MAYNEORD (10) it was thus possible to determine the intensity distribution for the »equatorial»

plane of the needles, and the result is shown in the usual form of isodose curves in figure 2. The distribution is fairly satisfactory, and throughout the shaded area, corresponding to the position of the main embryonic tissues, the intensity may be taken as uniform to within $\pm$ 12 %.

Similarly it was found that the volume occupied by the main embryonic tissues was a region of approximately uniform intensity estimated as 40 ± 7 Imc. The extra-embryonic system of blood vessels of course received a higher intensity and correspondingly larger doses of radiation but this source of error could not be prevented.

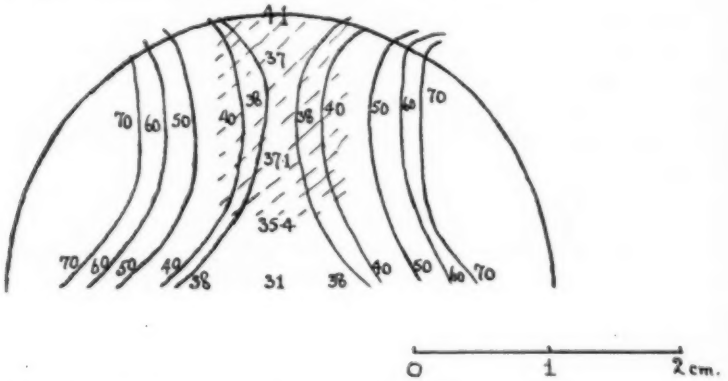

Figure 2. Isodose curves in equatorial plane of Needles.

Since the completion of these experiments it has been possible to make actual measurements of the intensity by means of SIEVERT's condenser chamber technique (11). Small spherical chambers of the type designated (1—1) 10 (11) were used in conjunction with a WULF bifilar electrometer. These were charged at Westminster Hospital Annexe, London, taken to Cambridge for exposure to the radium and brought back to London for the measurement of residual charge.

The exposures were carried out using a wax model of an egg. A small hole was drilled into the wax to accommodate the SIEVERT chamber, so that it corresponded in position to a chick embryo *in ovo*. The chambers were calibrated in air with a 200 mgm. radium tube having a total filtration of 0.3 mm. Monel metal + 0.5 mm. platinum, at a distance of 10 cm. which was large compared with the size of either the radium source or the condenser chamber.

Values were thus obtained for two positions viz. the centre of the region that would be occupied by an embryo, and a point 5 mm. from this centre. The values were 41.7 and 40.2 Imc respectively, in very close agreement with the calculated value (average 40 Imc). The measurements

suggest that the variations of intensity were actually even smaller than the estimate reached by calculation.

Results

a) Delayed lethal dose and the age of embryo

The main results are summarized in Table I. Sometimes death occurred from other causes than irradiation. In practically every case it was possible, however, to detect this by looking closely at the stage of development reached by the embryos before death. In the case of embryos more than 2 days old transillumination of the egg showed up the embryo so clearly that it could be determined for certain whether the embryo was alive at the time of irradiation.

These results show a wide variation in response to radiation. This may be partly due to an unequal lag in their early development, especially as a large number of the experiments were carried out during the winter months when a retardation in development of embryos is frequently found. A good deal of information, however, may be obtained from

Table I

Age of embryo at irradiation	Exposure to radium	Number of embryos irradiated	Results	Controls
22—26 hours or 1 day	4 hours	6	2 dead, 4 alive	5 alive, 1 infertile
	5 »	6	5 dead, 1 nearly dead	5 » , 1 dead
	6 »	6	6 dead and rather necrotic	4 » , 1 dead, 1 infertile
46—50 hours or 2 days	5 hours	6	1 dead, 5 alive	5 alive, 1 infertile
	6 »	6	3 almost dead, 3 alive	6 »
	7 »	6	4 dead, 2 nearly dead	5 » , 1 infertile
3 days	7 hours	6	1 dead, 1 almost dead, 4 alive	6 alive
	9 »	6	2 dead, 1 almost dead, 3 alive	5 » , 1 infertile
	10 »	6	5 dead and necrotic, 1 dead	5 » , 1 »
4 days	12 hours	6	2 dead, 4 alive	6 alive
	14 »	6	3 dead, 3 alive	6 »
	15 »	6	4 dead and necrotic, 2 nearly dead	5 » , 1 infertile
5 days	18 hours	6	3 dead, 3 alive	6 alive
	22 »	6	4 dead, 2 alive	6 »
	24 »	6	5 dead and necrotic, 1 nearly dead	5 » , 1 infertile
6 days	18 hours	6	2 dead, 4 alive	6 alive
	20 »	6	1 dead, 5 alive	6 »
	24 »	6	4 dead, 2 alive	6 »
	26 »	6	6 dead and necrotic	5 » , 1 infertile

these results with regard to the relation between radiosensitivity and age of embryo.

By taking that exposure to the radium source which, when given to 6 embryos will produce 6 dead embryos within 24 hours, the results summarized in Table II are obtained. These are shown graphically in figure 3.

Table II

Age of embryo at irradiation	Lethal exposure to radium
1 day	5 hours
2 »	7 »
3 »	9.5 »
4 »	15 »
5 »	22—24 »
6 »	24—26 »

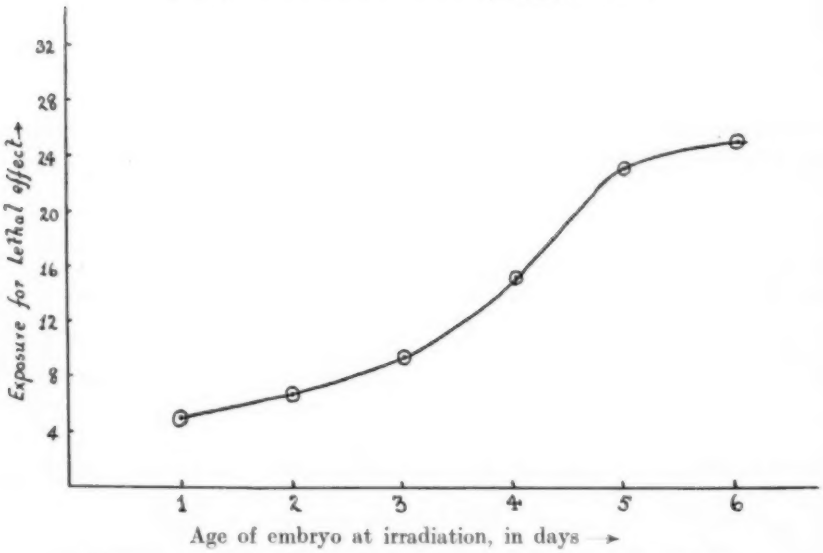

Figure 3. Relation between lethal exposure and age of embryo.

In the case of the 5 and 6 day embryos (which had to be given very lengthy exposures in order to produce a lethal effect), the exposure values are most probably rather lower than they should be strictly in comparison with those for the younger embryos. This is due to the increased size of embryo which causes it to receive a larger dose than that estimated,

owing to the slightly higher incident intensity. The experimental conditions also differ from those for the younger embryos since the total period of incubation is relatively long due to the extended period of irradiation. It was indeed for this reason that the experiments were not extended to embryos older than 6 days.

From the graph (Fig. 3) it seems that for the first three days there is a regular decrease of the radiosensitivity of the developing embryo with increase of age, the three points corresponding to this portion of the graph lying very closely on a straight line. After 3 days there is a sudden marked decrease in sensitivity as indicated by the sudden increase in lethal exposure required for a 4 day embryo from that corresponding to one of 3 days. From this time up to 5 days the rate of decrease of sensitivity is more rapid, after which it slows down again so that the radiosensitivity seems to be much about the same for both 5 and 6 day embryos. This latter suggests that the maximum exposure for lethal effect at any age is being reached, or in other words, after 5 days the radiosensitivity of the chick embryo may be approximately constant.

b) Macroscopic observations on the effects of irradiation

1 and 2 day embryos. In these embryos the most obvious feature was the very marked difference between the effect in the »area pellucida» and the effect in the »area opaca». After a lethal exposure the blood vessels of the »area pellucida» were completely destroyed, the actual tissue of the embryo lying almost free inside a reddish ring representing what had been the »area opaca». This area consisted of capillaries of clotted blood and presented a beaded pattern of irregular markings.

After an exposure, just sub-lethal, the plexus of blood vessels in the irradiated embryos was found to be much more sparse than in the controls. The smaller vessels had degenerated while the larger ones were still intact.

In general the irradiated embryos were always less well developed than the controls.

3 day embryos. After a lethal dose they presented much the same appearances as the 1 and 2 day embryos, the vessels of the »area pellucida» usually being destroyed whilst those of the »area opaca» showed clotting. In some cases the embryos were found to show the whole pattern of the blood system in the »area pellucida» without any blood corpuscles within the vessels, which appeared as a yellowish plexus. This contrasted with the clotted blood in the »area opaca» which never completely lost its red colour, even after lethal exposures.

With the exposures given the irradiated embryos were always found retarded in development and usually showed a dark red patch in the region of the brain.

4—6 day embryos. When these had received a lethal dose the flesh of the embryo was found very reddened and rather necrotic while the blood vessels were completely destroyed. Very exaggerated effects were always found in the region of the brain which showed a very dark red or almost black clot of blood. If the dose had been just sublethal the embryos were found with only the larger vessels present, all the smaller ones having been completely destroyed.

After lethal exposures a slight but not very definite retardation of the growth of the embryos was noticeable.

Part II

The object of the following experiments was to investigate the effects of short exposures (i. e. 5 hours or less) on chick embryos, left to incubate subsequent to irradiation. These doses are no greater than that found to be lethal to one-day embryos under the experimental conditions described in Part I of this paper.

The experiments were carried out exactly as already described. For each reading 6 embryos were irradiated, and each had its corresponding control. The irradiations lasted 2, 3, 4 and 5 hours respectively. After exposure the chicks were left to incubate for 20—22 days but were examined by transillumination at intervals and opened if the chick was obviously moribund to determine the stage of development of the chick at death. Eggs were opened and examined if the chick did not hatch out normally after 3 weeks.

Results

The results obtained from this set of experiments are summarized in Table III.

It is seen that exposures to the radium of 4 or 5 hours subsequently prove lethal to the embryos whatever their age at the time of irradiation. The period of survival after irradiation is, however, dependent upon age, and roughly it may be said that the older the embryo is when irradiated, the longer is death delayed. When hatching occurs it takes place at about the same time in irradiated chicks as for the corresponding controls.

By calculating the average age of the embryos at which death occurred following irradiation and subtracting the age at the time of

Table III

Age of embryos	Number used for each exposure period	2 hours irradiation	3 hours irradiation	4 hours irradiation	5 hours irradiation
1 day . .	6	3 hatched out. 1 fully developed.	1 hatched out.	Dead 1.3 days after irradiation, on an average.	Dead 1.0 days after irradiation, on an average.
2 days . .	6	2 hatched out. 3 fully developed.	1 hatched out.	Dead 2.7 days after irradiation, on an average.	Dead 2.1 days after irradiation, on an average.
3 days . .	6	2 hatched out. 3 fully developed.	1 hatched out. 2 fully developed.	Dead 4.0 days after irradiation, on an average.	Dead 2.0 days after irradiation, on an average.
4 days . .	6	3 hatched out. 1 fully developed.	1 hatched out. 1 fully developed.	Dead 9 0 days after irradiation, on an average.	Dead 3.5 days after irradiation, on an average.
5 days . .	6	3 hatched out. 2 fully developed.	2 hatched out. 2 fully developed.	Dead 10.0 days after irradiation, on an average.	Dead 8.0 days after irradiation, on an average.
6 days . .	6	3 hatched out. 2 fully developed.	1 hatched out. 1 fully devcloped.	Dead 9 8 days after irradiation, on an average.	Dead 6.5 days after irradiation, on an average.

Total controls = 144 viz: 64 hatched out.
41 fully developed but died in shell.
21 dead before term.
18 infertile.

irradiation, it is possible to obtain the average period of survival after a given dose, which may be taken as a measure of the radiosensitivity of the embryo. Such survival periods for the various aged embryos corresponding to exposures of 4 and 5 hours are given in columns 5 and 6 of Table III while the same results are shown graphically in figure 4. These curves show the change in radiosensitivity of the chick embryo with age when this sensitivity is measured in terms of the survival period after a small, though subsequently lethal, dose of radiation.

It is seen that the curves are very similar to that described in Part I. They confirm the earlier findings that the sensitivity of 1 to 3 day embryos decreases very regularly, after which it decreases very much more rapidly up till 5 days. These curves also suggest that after 5 days' incubation the radiosensitivity may possibly increase, but in view of the fact that 6 day embryos receive a slightly higher radiation intensity by reason of their larger dimensions, it is not safe to take this as established. It seems much more likely that the sensitivity to radiation is reaching a steady value at about 5 or 6 days as is suggested by the curve obtained in Part I and that given in Figure 4 for survival after 4 hours exposure to the radium.

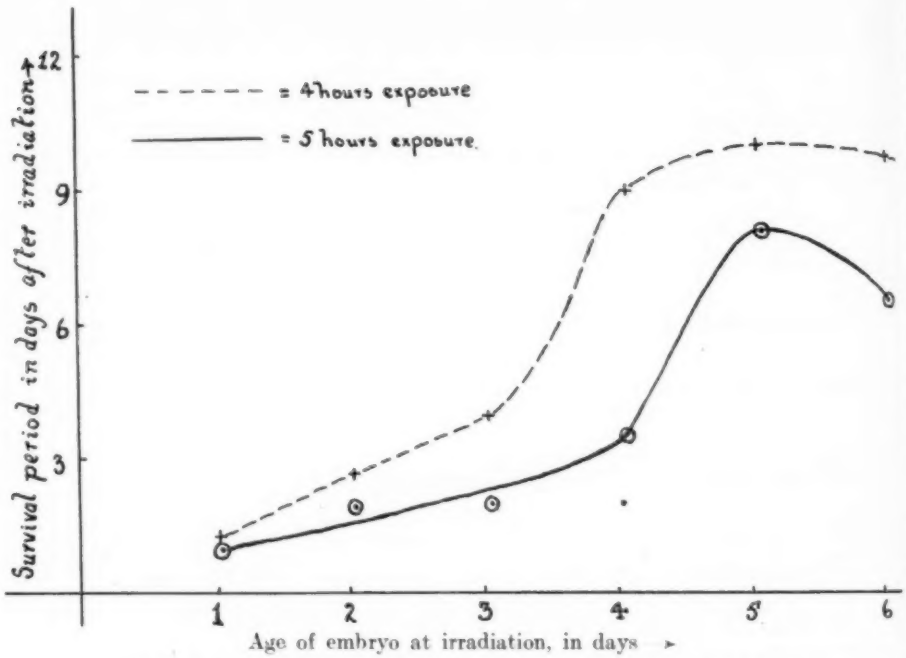

Figure 4. Relation between survival period and age of embryo.

The results obtained with exposures of 3 hours suggest that this exposure is somewhere near the »border-line» value that permits complete recovery of an irradiated embryo. Exposures longer than 3 hours have been shown to be subsequently lethal, those of 3 hours permit hatching or complete development in a number of cases, while shorter exposures such as 2 hours will allow recovery and permit practically normal development. Thus the results obtained for 2 hour-exposures are not unlike those of the controls, a good percentage of hatchings occurring after irradiation.

It is to be noted that the »border-line» exposure appears to be approximately the same for all embryos, no matter what their age at the time of irradiation. When, however, a dose is given greater than this, the period of survival after irradiation depends on the embryo's age when it was irradiated.

Whether the chicks successfully hatched after being irradiated in the early stages of their development are perfectly normal is a question of considerable interest. It is hoped therefore to make this the subject of a separate study.

The results of these experiments contrast very markedly with those obtained by TUR (12) in his early work. After continuous irradiations of chick embryos with a quantity of radium (details not given), he found monstrous embryos on subsequent examination. TUR's results are probably explained by the non-uniform intensity distribution throughout the embryo causing a gradation of effect. Monstrosities were never found in my own experiments.

General Discussion of Results

It is possible that the marked difference between the effects of irradiation in the »area pellucida» and those in the »area opaca» is connected in some way with the difference in the rates of growth in the two areas. At this period of development of the chick (2 day embryo) the vessels of the pellucida are rapidly elongating and it is probable that cell division (which is most susceptible to radiation) may be more frequent in the endothelial cells of this region than in those of other vessels. In this connection TUR (12) states that »generally speaking, the central parts of the embryos underwent the most profound alterations, the peripherial portions showing only insignificant modifications.»

The first effect of these lethal doses of radiation is upon the blood corpuscles, causing them to bunch together, (at this stage of the embryo's development true clotting of the blood cannot occur since the necessary constituents are absent) and then follows a subsequent degeneration of the vessels themselves. In some cases the whole plexus of vessels was observed without any actual red blood. The smaller vessels degenerate first and the largest last of all.

The change in the radiosensitivity of the chick embryo appears to be correlated with its development. From a graphical expression of data given by LILLIE (13) it is apparent that the rate of development of the chick embryo (as measured in terms of somite formation) falls off rapidly and regularly during the first three days of incubation, after which it decreases much less rapidly. This would seem to suggest that the faster the rate at which the chick is growing, the more radiosensitive it is, provided the doses of radiation given are sufficient ultimately to prove lethal. If the dose given is below what has been called the »border-line» exposure, and hatching is adopted as a criterion of effect, it has been shown that the sensitivity is approximately the same whatever the age of embryo.

Although these chicks hatch out, the radiation they received produces profound changes in the frequency of cell division in the tissues of the embryo and causes a considerable amount of degeneration; doses of even

less than one-sixth of the »border-line» dose cause well-marked »direct» effects on the tissues (14).

It would seem that the »border-line» dose may be just short of the value to cause some profound change in the nature of the blood corpuscles of the developing chick embryo. Thus doses below that value probably produce only »direct» effects on the tissues (from which effects recovery takes place eventually), while when it is exceeded a change in the blood corpuscles occurs so that »indirect» effects are added and play the most important rôle in producing subsequent death.

It is interesting to compare these results with gamma rays with those obtained by other experimenters who have studied the effects of roentgen rays on the developing chick embryo.

STRANGEWAYS and FELL (15) irradiated 1 and 6 day embryos simultaneously with rather soft roentgen rays (90 K. V. and a thin celluloid filter) giving doses of 270 »e» and 150 »e» (as measured by a calibrated FRIEDRICH iontoquantimeter) and allowed some to incubate for a further 24 hours before opening them for examination. They found that in the case of the younger chicks, »embryos fixed after 24 hours following exposure had undergone a partial recovery as represented by the return of mitosis and an advance in development», whereas for 6 day embryos they state »the tissues of embryos incubated for 24 hours after irradiation showed no sign of recovery and were in a state of partial disintegration».

There is some difficulty in making any adequate comparison of such results because as yet there is no satisfactory expression of the two sets of dosage in terms of a common physical unit. A biological comparison may be made, however, by equating doses of roentgen-rays and gamma-rays that have been shown to produce the same effect, viz: a given percentage reduction in cell division as recorded by the technique of tissue culture (1, 5, 16).

STRANGEWAYS and HOPWOOD (16) showed that a dose of roentgen rays equal to 5 »e» delivered at an intensity of 5 e per min. produced a fall in the amount of cell division in tissue cultures down to 60 % of the normal value. This was found with the same apparatus as used by STRANGEWAYS and FELL (15) and later by LOVE (17) who studied the reduction in mitosis by roentgen radiation and obtained comparable results.

From the data given by CANTI and SPEAR (1) it is possible to calculate the intensities and doses of gamma rays used in terms of Imc. units and to find that a reduction to 60 % of normal cell division is produced by a dose of about 50 r delivered at intensities ranging between 24 r and 64 r per min.

Thus, using this biological effect as a bridge, it seems that 5 »e» is approximately equivalent to 50 »r» or 1 »e» is the same as 10 »r» and an

intensity of 5 e per min., as used by STRANGEWAYS and FELL corresponds to 50 r per min., whilst the doses they used would be 1,500 r and 2,700 r respectively. By using the less reliable skin erythema dose as a link between the two units HOPWOOD and DONALDSON (18) suggest the relation 1 »e» = 5 »r».

MAYNEORD and ROBERTS (19), KAYE and BINKS (20), and others, have shown that if gamma radiation is measured by means of an ionisation chamber having »air walls» of a thickness at least equal to the ranges of the electrons produced in them by the radiation, then 1 Imc has an average value of 8.0 r/hr. If conditions corresponding to a thick »air wall» are maintained with the experimental biological material (as is very approximately the case in the present work) it is legitimate to assume this value for converting the radiation intensity used into r units.

Thus an intensity of 40 Imc = $8 \times 40 = 320$ r/hr or 5.3 r/min. whilst the various doses used, when converted into r units become:

»Border Line» dose permitting recovery (3 hours' exposure) = 3×320 r = 960 r.

Lethal dose for 1 day embryo (5 hours' exposure) = 5×320 r = 1,600 r.

Lethal dose for 6 day embryo (25 hours' exposure) = 25×320 r = 8,000 r.

Thus in the case of roentgen rays, when the *same* dose of radiation (disregarding its actual magnitude for the moment) is given to both 1 day and 6 day embryos and these are allowed to incubate for a further 24 hours, the effects on the older embryos are very much more severe than in the case of the younger ones.

With gamma rays however, it has been shown that in order to produce the same degree of effect, namely death, on 1 and 6 day embryos, the dose required for the latter is five times that required for the former. Moreover, if 6 day embryos are exposed to the radium for 5 hours (the lethal exposure for 1 day embryos), it was found that the embryos appeared, macroscopically, quite normal.

Considering the actual magnitude of the doses of radiation used, it seems that to produce effects on 6 day embryos such as were found by STRANGEWAYS and FELL after giving a dose of roentgen rays equal to 1,500 r, requires a dose of 8,000 r when gamma radiation is used.

There thus appears to be a marked difference between the degree of effects produced by rather soft roentgen rays and those brought about by gamma rays. In this same connection it is interesting to consider the results obtained by COLWELL, GLADSTONE and WAKELEY (21, 22, 23) in their work on the effects on the chick embryo of roentgen radiation of

several different wave-lengths. In some experiments in which they irradiated young embryos (21) they found that »within the limits of radiation investigated the effects seem rather to depend on the total amount of radiation reaching the embryo than upon variations in its hardness». When however, embryos of 4 days or more were used it was concluded (22, 23) that »the most pronounced changes occur in specimens which have been subjected to unfiltered (soft) rays as contrasted with screened (harder) rays».

It is recognized of course that the »time-factor» is an important consideration (by reason of the very different intensities that were used in the two sets of experiments) but although a differential effect is not conclusively proved, the results at least suggest that further investigation of the subject would yield a fruitful result.

Acknowledgements

My thanks are due to the Medical Research Council for the loan of the radium needles used throughout this work and also to the British Empire Cancer Campaign whose financial assistance made the work possible.

I should also like to thank Dr H. B. Fell, Dr Spear and Dr A. Hughes for their helpful advice and suggestions during the course of the work and its preparation for publication.

SUMMARY

An arrangement of radium needles suitable for the approximate uniform irradiation of 1- to 6-day chick embryos is described.

Graphical relations are found between the age of embryo and its radiosensitivity as measured by two different methods. It is shown that the radiosensitivity decreases regularly for the first three days of incubation, more rapidly from three to five days and then probably remains fairly stationary. It is suggested that these findings may be correlated with the rate of growth of the embryo.

There appears to be a maximum dose of gamma radiation from which embryos may recover and hatch, and this appears to have the same value for all embryos from 1 to 6 days incubation. This dose probably produces some irreversible effect through the blood circulation.

The suggestion of a possible differential action of roentgen rays and gamma rays on the developing chick embryo is put forward as a result of the comparison of this work with other investigations.

ZUSAMMENFASSUNG

Es wird eine Anordnung von Radium-Nadeln beschrieben, die eine annähernd gleichmässige Bestrahlung von 1—6 Tage alten Hühnerembryonen gestattet.

Mit 2 verschiedenen Methoden lassen sich graphisch darstellbare Beziehungen zwischen dem Alter der Embryonen und ihrer Radiosensitivität aufzeigen. Während der er-

sten 3 Tage der Bebrütungsperiode sinkt die Sensitivität gleichmässig langsam, zwischen dem 3.—5. Tag viel schneller ab und bleibt dann ziemlich gleichmässig. Dieses Verhalten mag in Zusammenhang stehen mit der verschiedenen Wachstumsgeschwindigkeit der Embryonen.

Die Maximaldose von gamma-Strahlen, die noch eine Erholung der Embryonen und ihr Ausschlüpfen aus dem Ei zulässt, scheint für Embryonen des 1.—6. Tages die gleiche zu sein. Der Tod der Embryonen vor dem Ausschlüpfen aus der Schale ist wahrscheinlich mit durch die Bestrahlung verursachten Störungen im Blutkreislauf zu erklären.

Ein Vergleich unserer Befunde mit denen anderer Untersuchungen scheint vielleicht für eine verschiedene Wirkung von Röntgen- und Radiumstrahlen zu sprechen.

RÉSUMÉ

Il est décrit une disposition des aiguilles de radium convenant à une irradiation à peu près uniforme d'embryons de poule de 1 à 6 jours.

Des relations graphiques sont trouvées entre l'âge de l'embryon et sa radiosensibilité mesurée de deux façons différentes. Il est montré que la radiosensibilité diminue régulièrement durant les trois premiers jours de l'incubation, plus rapidement du troisième au cinquième jour et reste après cela probablement environ stationnaire. Il est suggéré que cet état de chose peut être en rapport avec la vitesse de croissance de l'embryon.

Il semble qu'il y ait une dose maxima de radiation gamma de laquelle les embryons peuvent reprendre et éclore, et elle semble être aussi forte pour tous les embryons de 1 à 6 jours d'incubation. Cette dose produit probablement quelque effet irréversible par la voie de la circulation du sang.

La possibilité d'une action différente des rayons X et des rayons gamma sur l'embryon de poule en évolution est présentée comme le résultat d'une comparaison entre ce travail et d'autres observations.

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FROM THE PHYSICAL LABORATORY OF THE RADIUMHEMMET
(CHIEF: R. M. SIEVERT)

A PORTABLE SECONDARY STANDARD FOR ROENTGEN RAY MEASUREMENTS[1]

by

R. Thoræus

In a previous paper (1) I have given a detailed description of the air-ionisation chamber, used as the primary standard in Swedish roentgen ray work. A rather generous estimation of the margin of error of this standard chamber, when measuring the roentgen intensity in *r*/min, gave $\pm$ 1.5 per cent. Further investigations seem to indicate that, when all precautions and the best care are taken, it is possible to reduce the margin to about $\pm$ 1 per cent. This seems to be in good accordance with the results of other authors, for instance KAYE and BINKS (2).

Because of both the dimensions and the positive requirements of constancy such a standard chamber can only be used in a stationary mounting. Thus, for all calibrations and measurements in other places, more or less far from the laboratory, a secondary standard is necessarily required. In our Laboratory, which, by its Ambulatory Department has a very extensive collaboration with not less than 46 hospital roentgen therapy departments, administered by expert radiologists, the need of a good portable secondary standard is very pronounced. A secondary standard for this purpose was devised at a rather early date (1925) by SIEVERT. The properties and features of this instrument have been discussed by SIEVERT (3) and by the author (1). As the ambulatory department has been administered since 1927 by the author, my practical experience of this instrument is rather extensive. In my opinion it has proved to be very reliable and constant.

From the beginning this secondary standard was mainly intended for measurements in rather wide primary beams. Thus it was not suitable for measurements of the total intensity or amount of radiation at the surface of or within an irradiated body which, however, nowadays is frequently required. These facts were the reasons why, in 1931, I planned

[1] Submitted for publication Aug. 23rd, 1935.

a new instrument, a description of which will be given in this article. A great deal of the measuring results given in previous articles (4) have been obtained with this new instrument, which was built in the beginning of 1932.

The new instrument is built according to that modification of the well-known electro-static principle which was at first employed by SIEVERT (5) and consists consequently of two separate units, viz. the condenser-chamber unit and the reading unit. The former one consists of a spherical graphite chamber (outside diameter 16 mm) which, by a screw connection, is rigidly fastened to a condenser having a solid dielectric medium of a very high insulating power. The only air-space within the whole unit is that in the ionisation chamber. By this arrangement the unit, excepting the chamber itself, is practically independent of eventual irradiation. Furthermore, the chamber is quite air-tight. Thus the

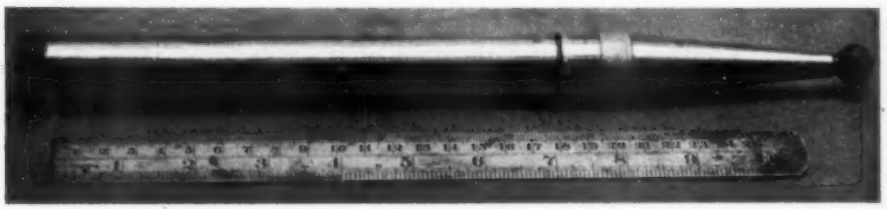

Fig. 1.

ionised amount of air within the chamber is constant and because of this corrections regarding temperature and air-pressure are not required. Fig. 1 shows the exterior of the whole unit ready for use. As may be seen the condenser is constructed to form the handle of the unit.

The condenser-chamber unit is charged to rather a moderate potential, generally about 180 volt, and is then ready for use. After irradiation the remaining potential is read by putting the unit on an electrometer. The difference between the condenser potential after and before the irradiation, that is the potential drop, is calculated and then divided by the time of the irradiation. The value thus obtained is suitably expressed in volt per minute.

During the irradiation the condenser-chamber unit is quite free from the reading instrument. This means a very high degree of flexibility which permits measurements to be carried out at any place within a roentgen department or a laboratory without moving anything else than the condenser-chamber unit. When measurements are to be made at two or more places simultaneously a corresponding number of condenser-

chamber units must be used, whereas the electrometer unit itself is used for reading all of them.

The electrometer in the reading unit is a Lutz-Edelmann single string instrument in which both the string and the knife-edges are adjustable by means of micrometers. The knife-edges are charged to $\pm$ 90 volt by two small batteries. As there is practically no current in this circuit, the capacity of these batteries can be kept rather small. Batteries for this purpose have, on my request, been built by the Swedish Pertrix Comp. After some trials they succeeded in preparing small units which seem to have a very good life-length. Their dimensions are only $130 \times 115 \times 60$ mm and the weight is 1.26 kg per unit of 90 volt. Even if used very frequently they will last for more than one year. During such a period their potential decreases to about 85 volt. As, however, the sensitivity of the electrometer can easily be checked whenever wanted and at all events must be checked after each transportation, such a slow decrease of the potential of the knife-edges is quite without importance.

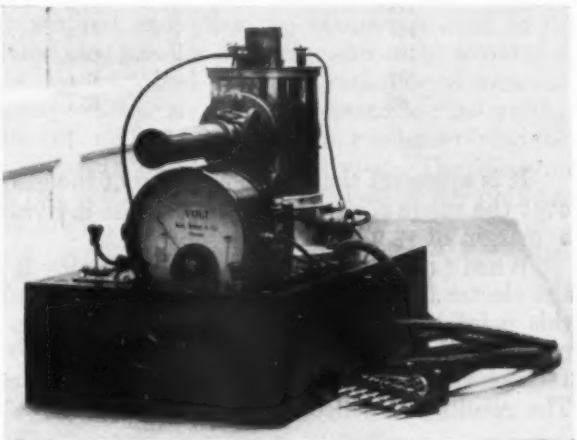

Fig. 2.

Fig. 2 shows the complete reading unit ready for use. The voltmeter by which the sensitivity of the electrometer is checked is clearly seen. The box which forms the fundament contains the two knife-edge charging batteries.

For charging the condenser-chamber unit and for checking the sensitivity of the electrometer two ordinary 90 volt anode batteries are used in series. These batteries are enclosed in a separate box, and the potential is divided in six steps. By this arrangement the sensitivity of the electrometer can be checked for a corresponding number of potentials. Experience has shown, however, that the electrometer is, to an astonishing degree, insusceptible to transport vibrations, and in general it has been found sufficient to take one checking for the maximum or charging potential only.

For the practical use of a secondary standard of the type described above it is very convenient if the sensitivity of the electrometer can be adjusted to be constant all over the scale or at least over the range used. If this is not the case a diagram of the sensitivity in volt per scale division against the deflection must be used to recalculate the readings into volts. In table 1 I give the calibration results of the electrometer used.

Table 1

Potential in volts	Deflection in scale divisions	Sensitivity in volt per scale division
174	87.0	2.00
149	74.2	2.01
123	60.8	2.02
97	48.1	2.02
66	33.1	2.00
		Average = 2.01

It is apparent that the sensitivity of the electrometer is very constant over the range commonly used. All the individual values are covered by a margin of ± 0.5 per cent.

When estimating the measuring accuracy it is of importance to know the electrostatic leakage of the condenser-chamber unit. Information on this point has been gained by observations on different occasions. The unit has then been charged to the commonly used potential of about 180 volts, and the leakage after different numbers of hours has been read. The results are collected in table 2.

Table 2

Date of reading	Number of hours	Leakage in volt per hour
$^{18}/_{9}$ 34	100	0.22
$^{25}/_{9}$ 34	166	0.27
$^{28}/_{2}$ 35	18	0.17
$^{2}/_{3}$ 35	16	0.19
$^{25}/_{6}$ 35	96	0.22

When packed for transport the chamber is unscrewed from the condenser. An observation over 18 hours of the leakage in this position gave 0.22 volt per hour.

From table 2 an average leakage of 0.21 volt per hour is calculated. The reading accuracy of the electrometer is 0.1 scale division which, with the generally used sensitivity of about 2 volt per scale division, corresponds to about 0.2 volt. Thus the leakage in volt per hour is practically the same as the reading accuracy. In general the potential drop in the condenser due to an irradiation is kept at about half the initial potential or somewhat more. The latter being about 180 volt, we thus get a drop of 90—100

volt. This means that the error introduced in the measurements by the leakage is smaller than 1 per cent when the time between charging and reading does not exceed 5 hours. In practical measurements the time between charging and reading is shorter than one hour, and then the error due to leakage can be neglected.

For the use of a secondary standard it is very important to know how far it is parallel with the primary standard. To get a detailed knowledge on this point rather extensive calibrations have been carried out.

The first step was then to investigate how far the condenser can be discharged by irradiation without exceeding the saturation limit of the chamber. On the other hand, too small a discharge should be avoided as the measuring accuracy is then impaired. The saturation tests were carried out in the following way. Using an unfiltered beam, a tube voltage of 145 kV and two different milli-amperages, the condenser chamber unit was irradiated for different numbers of minutes. The charging potential of the unit was 182 volt, and for each irradiation the obtained potential drop in volt per minute per mA was calculated. The result is collected in table 3. Within the rather wide range investigated, the values agree very well and indicate a saturation limit below 30 volt.

Table 3

Tube-current 1 mA				Tube-current 5 mA			
time of irradiation in minutes	potential drop in volt	volt per minute	volt per minute per mA	time of irradiation in minutes	potential drop in volt	volt per minute	volt per minute per mA
4	42.0	10.5	10.5	¾	39.5	52.7	10.55
6	62.5	10.4	10.4	1	52.0	52.0	10.4
8	82.0	10.25	10.25	1½ . . .	76.5	51.0	10.2
10	103.0	10.3	10.3	2	102.5	51.2	10.25
15	153.3	10.2	10.2	3	153.2	51.1	10.2

Calibrations between secondary and primary standards are in general only carried out for different radiation qualities without regard to the intensity. In this case, however, I have also included a calibration for different intensities of a constant quality. Using a tube voltage of 145 kV and an unfiltered beam, the intensity of which was mainly controlled by the milli-amperage and to some extent by the focal-distance, the secondary standard was calibrated against the standard chamber. The result is given in table 4 where k is the ratio r/min as obtained with the standard chamber to volt/min as read on the secondary standard, or in

other words k is the factor by which the reading on the secondary standard (volt/min) should be multiplied to obtain the intensity in r/min.

Table 4

Intensity r/min	k
5.6	1.07
10.5	1.06
11.2	1.06
21.3	1.055
30.4	1.04
32.5	1.03
42.7	1.04
53.0	1.04
58.2	1.03
90.0	1.02
123.0	1.03

When calculating the average we get 1.04 with a margin of $\pm$ 2 per cent which covers all the values within the rather wide range investigated. In practical work the range used is some 15—60 r/min and here the average is 1.04 $\pm$ 1 per cent.

The calibration with regard to different radiation qualities was carried out in the following way. By certain combinations of filter and tube voltage a number of qualities was obtained, and by selecting a suitable milli-amperage the intensity of each quality was kept, as near as possible, at 15 r/min. The results are collected in table 5, where k, as before, is the ratio between the readings of the standard chamber (r/min) and the secondary standard (volt/min).

When calculating the average value of k we get 1.06 $\pm$ 2 per cent which covers all the values corresponding to voltages of 100 kV and upwards. From table 4 we get, for 15 r/min, a k-value of 1.055 which is in extremely good accordance with the just mentioned average value.

Table 5

Filter and tube voltage	*HVL* of the beam	k
0 75 kV	0.95 mm Al	1.03
0 100 kV	1.25 mm Al	1.07
1 Al 100 kV	2.4 mm Al 0.1 mm Cu	1.085
4 Al 145 kV	0.3 mm Cu	1.08
0.5 Cu + 1 Al 165 kV	0.8 mm Cu	1.05
Comb. Tin filter 165 kV	1.6 mm Cu	1.052

From the calibration regarding saturation, the result of which is given in table 3, it is found that a potential drop of at least 150 volt in the condenser is allowed. Assuming a k-value of about 1.05 we find that the secondary standard will safely take an irradiation of 150—160 r, the latter value being considered as an approximate maximum. The most suitable amount of radiation is some 70—100 r. In cases of greater amounts to be measured the charging potential can be increased, eventually in combination with another condenser of a greater capacity. Small intensities, as met with in protective measurements, can be measured by using a greater ionisation chamber.

From the above it may be concluded, that the reading accuracy is quite sufficient and that the electrostatic leakage does not influence the total measuring accuracy, which is mainly determined by the calibration against the standard chamber. From the calibration results it is found that, for all intensities and qualities generally met with, the factor by which the readings in volt per minute is to be multiplied to obtain the intensity in r per minute is 1.04 with a measuring accuracy of $\pm$ 3 per cent.

The wall of the graphite ionisation chamber has a thickness of about $^3/_4$ mm and due to this its mecanical strength is not very great. It is certainly quite sufficient for all ordinary handling but nevertheless an accident may happen whereby the chamber is more or less damaged. For such an event the portable standard is equipped with a spare-chamber, being in all respects as far as possible equal to the ordinary chamber.

Table 6

Filter and voltage	Rel. intensity	K
0 100 kV	6.5	0.978
1 Al 100 kV	3.6	0.960
4 Al 145 kV	3.4	0.953
0.5 Cu + 1 Al 165 kV	2.4	0.963
Comb. Tin filter 165 kV	1.0	0.951
		Average = 0.961

The spare-chamber has been compared with the ordinary one and the result obtained is given in table 6 where K is the ratio between the readings obtained with the ordinary chamber and the spare-chamber. It is clearly seen that the readings of both the chambers are very nearly parallel, showing a practically constant difference, the average of which is 4 per cent. This difference is probably due to a corresponding differ-

ence in the ionised amount of air. The values in table 5 show that the ordinary chamber can be directly replaced by the spare-chamber. In such a case, however, the factor by which the readings in volt per minute is to be multiplied to obtain the intensity in *r* per minute should be reduced by 4 per cent.

As already mentioned the electrometer and especially the string system has proved to be very insusceptible to normal transport vibrations. However the string system may be damaged by an accident. For such an event the portable standard is equipped with a complete spare-system, kept in a certain casing and immediately ready to replace the ordinary system.

The instrument described above has now been in frequent use during nearly three years. Measurements have been carried out in primary beams, at the surface of and within phantoms, on patients during treatment, in short, in all kinds of ordinary measuring work. During this time the whole instrument has functioned very well.

SUMMARY

This article contains a description of a portable secondary standard for roentgen ray measurements, built according to the electrostatic principle and equipped with a spherical graphite ionisation chamber the outside diameter of which is 16 mm. The results of rather detailed calibrations and tests for the instrument described are given and discussed. It is found that, for all intensities and qualities generally met with, the readings are very closely parallel with those obtained by the standard air-ionisation chamber, and that the accuracy obtained when measuring the intensity in *r* per minute is ± 3 per cent.

ZUSAMMENFASSUNG

Der Aufsatz enthält eine Beschreibung eines tragbaren Sekundären Standards für Messungen von Röntgenstrahlen. Dieses Instrument ist nach dem elektrostatischen Prinzip gebaut und mit einer sphärischen Graphit-Ionisationskammer von 16 mm äusserem Durchmesser ausgestattet. Verf. berichtet und erörtert die Resultate von eingehenden Kalibrierungen und Untersuchungen des beschriebenen Instruments. Es wird gezeigt, dass die Ablesungen, für im allgemeinen vorkommenden Intensitäten und Qualitäten, sehr nahe denjenigen parallel sind, die man mit der Standard-Luft-Ionisationskammer erhält, und dass, bei Intensitätsmessungen in *r* per Minute, die Genauigkeit $\pm$ 3 Prozent ist.

RÉSUMÉ

Cet article contient la description d'un étalon secondaire, portatif, pour des mesures des rayons de röntgen, construé d'après le principe électrostatique et pourvu d'une chambre d'ionisation, sphérique et en graphite, d'un diamètre de 16 mm. Les résultats de calibrages et d'épreuves particulièrement détaillés pour l'instrument décrit sont donnés et discutés. Il est trouvé que pour toutes les intensités et qualités courantes les observations suivent de très près celles faites avec l'étalon à chambre d'aéroionisation, et que la précision obtenue en mesurant l'intensité en *r* par minute est de $\pm$ 3 p. 100.

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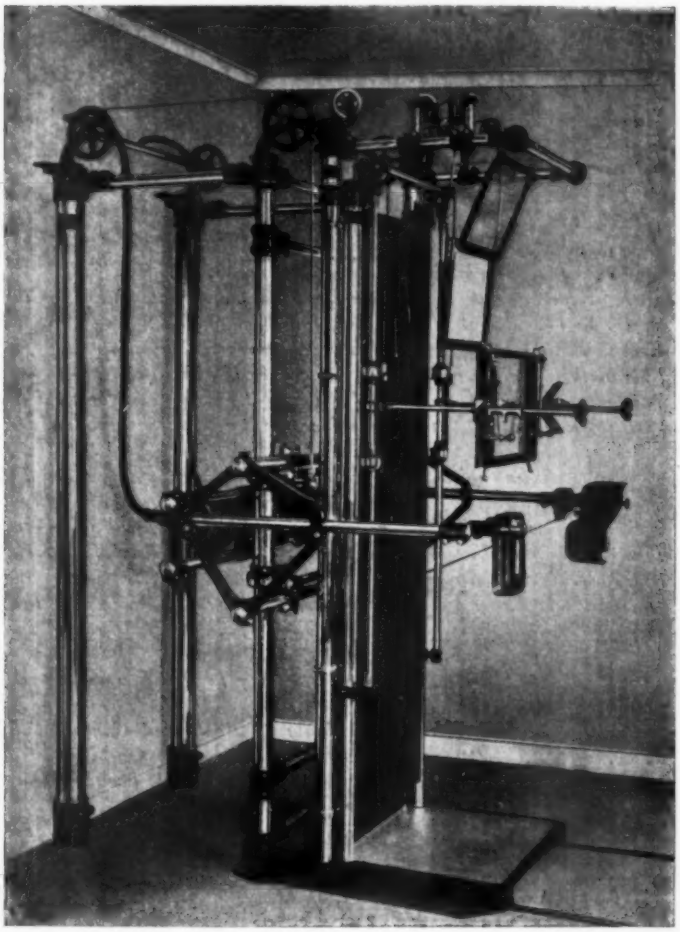

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